ALICE-USA Electromagnetic Calorimeter Project Management Plan

Draft 7-12-05

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(ALICE-USA Collaboration June 2005)

Contents

I. Introduction

The ALICE-USA Collaboration has proposed to build a large electromagnetic calorimeter for the ALICE Experiment at the LHC[1]. This is a draft management plan that addresses both the R&D project and the subsequent construction project (FY08-FY10) that will deliver the proposed electromagnetic calorimeter in a manner consistent with the physics research plan of the ALICE-USA Collaboration, the corresponding physics requirements for the detector and the ramp up of LHC heavy ion program. The full proposed electromagnetic calorimeter will consist of a barrel section providing, when completed, coverage for $-0.7 < \eta < 0.7$ and $0 < \phi < 2\pi/3$ (Figure I.1). In the present conceptual design, this coverage is built up from 12 separate super modules (Figure I.2) spanning this acceptance.

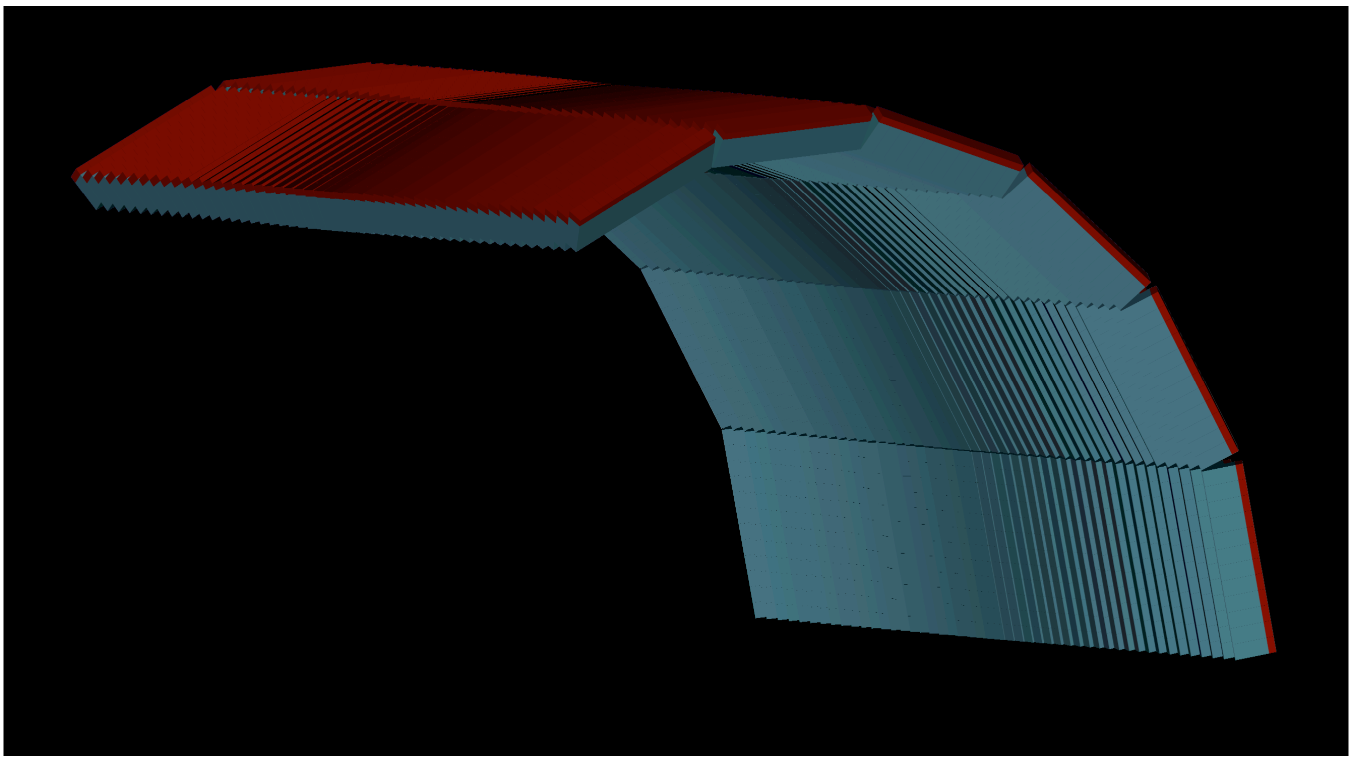


Figure I.1 Perspective view of the full ALICE-USA EMCal concept.

Each of the 12 super modules is composed of 288 distinct modules with each module comprising 4 separate energy measuring units or towers for a total of 13824 separate channels in the full detector. Each of these towers will deliver their data through two independent digitizing and data acquisition channels; one dedicated to the energy measurement and the other dedicated to the trigger.

[1] http://www.phenix.bnl.gov/WWW/publish/awes/ALICE/NSAC2004/

In addition to the detector elements and digitizing and trigger electronics, the final ALICE-USA project will provide the control, monitoring and analysis environment for the detector within the ALICE experiment to allow routine data processing through to physics observables (electrons, photons, π^{o}'s, η,…) at a level required to fully calibrate the detector and establish that it meets functionality requirements. The detailed physics requirements including the detector specifications are presented in Appendix A.

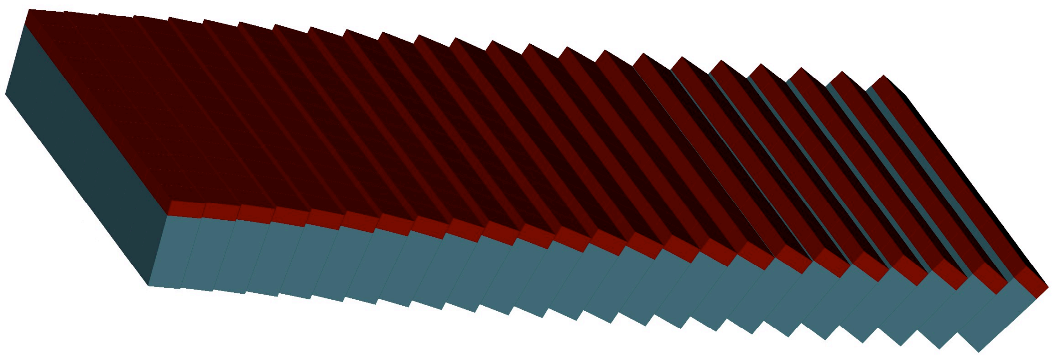


Figure I.2 ALICE-USA super module concept

The proposed ALICE-USA calorimeter is designed to work in the very complex environment of nucleus-nucleus collisions at the new energy frontier provided by the LHC. Measurements at this new frontier present a wide array of challenging technical issues and schedule challenges which must be confronted before construction of the full calorimeter can be undertaken. We have thus proposed a significant R&D project which precedes the construction project and is designed to mitigate the major cost, schedule, technical and programmatic risks associated with the full calorimeter project. The present **draft** management plan discusses the practices and procedures that will guide both this R&D effort and subsequent construction project along with details of cost, schedule and deliverables. The justifications for the individual elements of scope are given in the R&D proposal and will not be repeated here.

II. ALICE-USA EMCal Project Scope

The technical scope of the ALICE-USA calorimeter project is discussed in the following two sections. In section II.1 we discuss the proposed scope of the R&D phase of the project followed in section II.2 by the proposed scope of the construction phase of the project

II.1 ALICE-USA EMCal R&D Project Scope

There are 5 principal items of scope in the R&D phase of the project. These will be discussed separately in the order in which they appear in the WBS along with their associated deliverables.

1 WBS 1.1 - Detector Prototype for Test Beam Studies

(i) Module and super module mechanical prototypes will be studied to verify their mechanical stability under conditions to be encountered in the final ALICE calorimeter. This work will include analysis of the structures including analytic and finite element calculations and is intended to be at a level of detail sufficient to CERN safety reviews.

Deliverables:

- Experimental deflection and long term stability measurements of prototypes as a function of temperature and under realistic seismic stress for both module assemblies and super module sub assemblies.
- Module and super module structural finite element analysis

(ii) Tower optical studies will be undertaken to determine the optimum scintillator edge and surface treatment using final injection molded scintillator prototypes and the optimum wavelength shifting fiber density. Optimum techniques for in situ aluminizing wavelength shifting fibers will be determined.

Deliverables:

- Final scintillator tile design and preparation protocols
- Final fiber density design
- Final aluminized fiber bundle protocols

(iii) A detector prototype will be built consisting of a collection of 16 trapezoidal modules arranged in a 4x4 pattern for a total of 64 towers. A mounting structure for the modules will permit at least two stacking arrangements – one corresponding to the η=0 and one to the η=0.7 configurations encountered in the final detector. The towers will be instrumented with APDs and charge sensitive pre-amplifiers procured from the PHOS collaboration at CERN. The individual towers will follow the shashlik design with a total of 22 radiation lengths arranged in alternating layers of 1.6mm thick Pb and 1.6 mm thick injection molded polystyrene scintillator. A PHOS-style digitizer and readout chain will be procured from the PHOS collaboration at CERN.

Deliverables:

- 16 modules arrayed 4x4 on a mounting structure that allows both the η=0 and η=0.7 configurations that will be encountered in ALICE.
- Photo detectors, pre amps and readout electronics for all 64 towers
- A cosmic ray pre-calibration for all 64 towers and their associated LED test pulser.

- Digitizer, readout, DAQ and software system based on ALICE PHOS for 64 channels

(iv) A program of test beam measurements will be undertaken at Fermi Lab with hadrons, electrons and muons using the 64 tower prototype discussed above

Deliverables:

- Electromagnetic energy resolution measurements as a function of electron energy for the η=0 and η=0.7 configurations;
- Electromagnetic shower position resolution measurements for the η=0 and η=0.7 configurations;
- Electromagnetic shower shape measurements with emphasis on the tails and distortions near module boundaries for the η=0 and η=0.7 configurations;
- Muon and high energy hadron measurements for the η=0 and η=0.7 configurations needed for MIP calibrations and calibration tracking in ALICE
- Hadron energy deposition spectra and shower shapes needed for jet reconstruction algorithms.

2 WBS 1.2 EMCal Integration

(i) Detector integration studies and design work in close collaboration with ALICE engineering in CERN will establish all of the relevant detector volumes, routing paths, power and cooling, etc. for a fully installed and instrumented ALICE-USA Calorimeter. Prototypes will be used as needed to establish integration volumes in congested areas such as cable and/or cooling routing pathways through the access slots in the L3 magnet door. A full time ALICE-USA presence at CERN for a minimum of two years is required both to establish and then preserve the EMCal integration.

Deliverables:

- ALICE-USA EMCal integration plan fully documented in the ALICE database.

(ii) Design studies and analysis will be undertaken to advance the support structure conceptual design and establish a full integration plan including detailed installation protocols consistent with the available resources and space in the L3 underground area and vertical access tunnel.

Conceptual design and integration studies will be undertaken for super modules to establish a support structure interface plan and a detailed installation plan employing protocols consistent with the available resources and space in the L3 underground area and vertical access tunnel.

Deliverables:

- Support structure conceptual design and integration/installation plan documented in the ALICE database suitable for presentation to the LHCC.
- Super module to support structure interface design and super module installation plan documented in the ALICE database suitable for presentation to the LHCC.

3 WBS 1.3 EMCal Process Engineering

(i) Engineering designs, tool and die work and prototype studies including detailed QA/QC analysis (optical and/or mechanical as appropriate) will be performed for all injection molded module parts on small production run batches. The objective is to lay the groundwork for a commercialized production – at well understood cost - of the few $x10^6$ calorimeter parts that make up the final detector.

Deliverables: (See Figure II.1 and II.2)

- Engineering design, professional tool and die produced mold, and prototype samples of injection molded parts will be produced for the following calorimeter components:

	Part	Test Protocols
(a)	Scintillator tiles	Mechanical precision, optical attenuation length, surface finish and reflectivity, inclusion density
(b)	Optical mixer/diffuser	Mechanical precision, optical attenuation length surface finish and reflectivity, inclusion density
(c)	Optical fiber guide	Precision
(d)	Fiber grommet	Precision
(e)	Fiber cover	Precision
(f)	Rear matrix plate	Precision, elastic yield under pressure
(g)	Front matrix plate	Precision, elastic yield under pressure
(h)	Front cover	Precision
(i)	Module mounting plate	Precision, elastic yield, fracture point

(ii) Engineering designs, tool and die work and prototype studies including detailed QA/QC analysis will be performed for all metal stamped and laser cut parts.

Deliverables: (See Figure II.1 and II.2)

- Engineering design, professional tool and die fabrication, and prototype samples of Pb radiator plates. A small production run of plates for three different Pb alloys will be subjected to mechanical tests and QC evaluation.

- Engineering design, professional tool and die fabrication, and prototype samples of both the rear and front compression plate. A small production run of plates will be subjected to mechanical tests and QC evaluation.

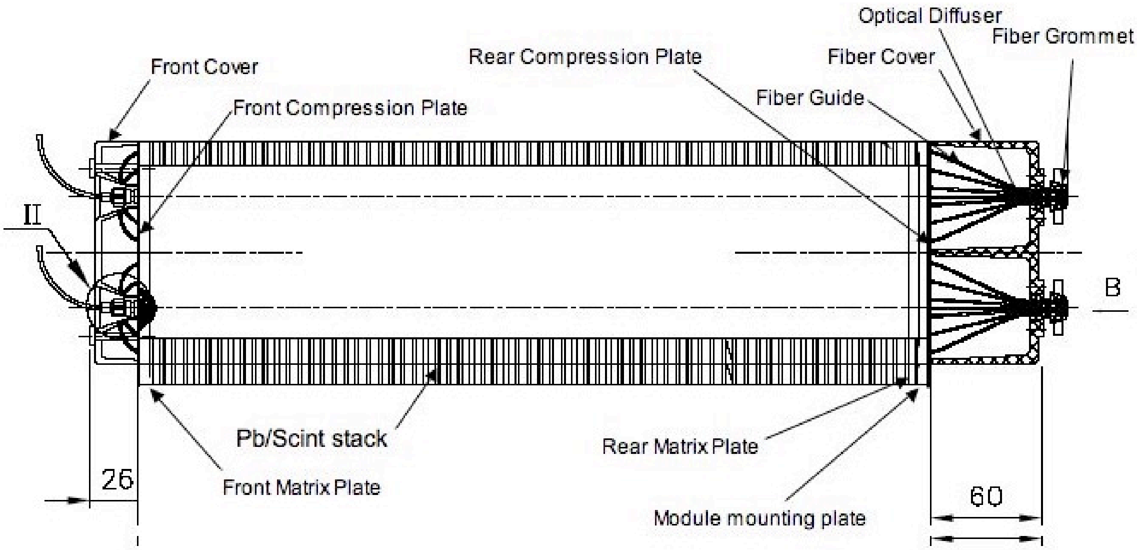


Figure II.1 Identification of many of the module mechanical parts

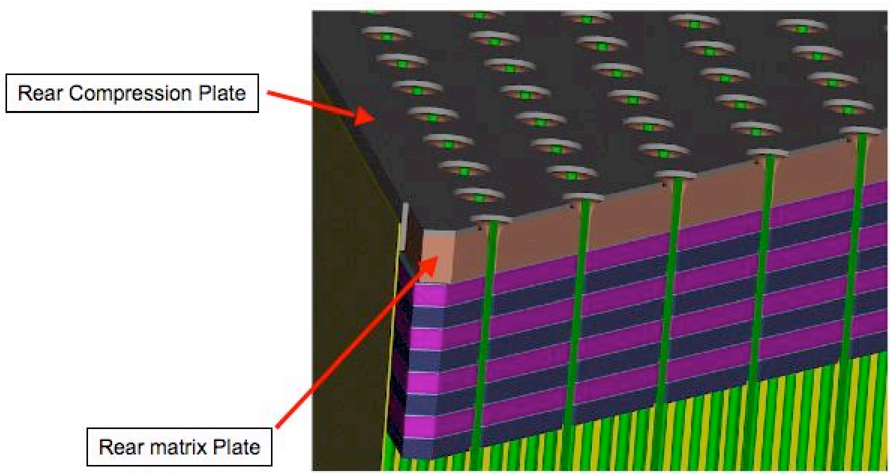


Figure II.2 Identification of some of the module parts

4 WBS 1.4 EMCal Support Structure

A support structure suitable to supporting a total weight of 105T (detector only) uniformly distributed in an arc of $\Delta\phi=2\pi/3$ outside the ALICE inner detectors is currently discussed as a component of the R&D project scope. In other scenarios, still under discussion, this support structure is treated as an independent US equipment acquisition or a CERN acquisition with no US involvement. Here, in this draft document, we proceed under the assumption that the support structure will be treated as a component of the scope of the R&D project. To the extent that the R&D effort is intended to minimize the cumulative risk in the ultimate MIE project, the inclusion of the support structure in the R&D effort is the most natural approach. The inclusion of the support structure in the R&D effort will permit mechanical tests that will:

(a) Minimize project technical risk by verifying the suitability of the L3 door frames and magnet foundations under the support structure attachment points to support an additional 105T load

(b) Minimize technical risk by verifying support structure deflections over the TPC /TRD subsystems under load do not interfere with the integration volumes of these subsystems

(c) Minimize technical risk by verifying module installation procedures before closure of underground area

(d) Minimize schedule and programmatic risk due to loss of installation window

Deliverables: (See Figure II.3)

- Final engineering design including finite element analysis with relevant seismic conditions
- Procurement of the support structure, delivery to CERN LHC Point-2 and installation in the L3 magnet
- Mechanical tests verifying a 105T capacity with deflections controlled at a level that guarantees no intrusion into other sub-system integration volumes.

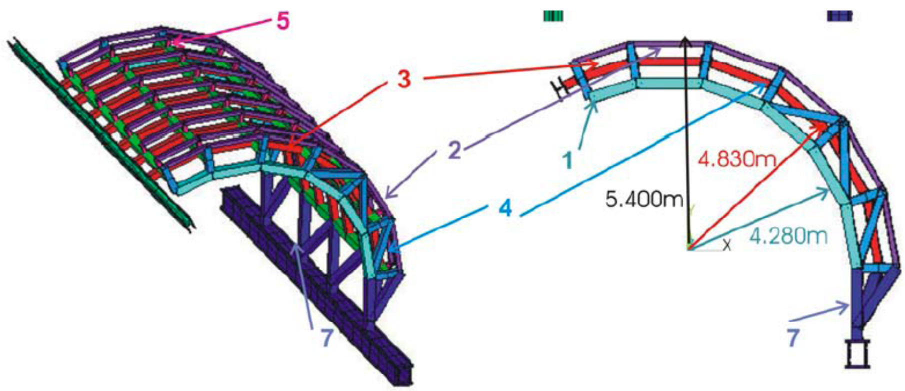


Fig. II.3 An overview of the present support structure concept to span 120 degrees in azimuth supported by the lower and upper rails.

5 WBS 1.5 EMCal Super module - 0

Construction, installation, integration and test of a single super module. This brings together all of the technologies and methods developed in this R&D program and allows a full test of the detector principle in the environment of PbPb collisions at the LHC.

Deliverables: (See Figure I.2)

- One ALICE-USA EMCal supermodule delivered to CERN LHC point-2 and installed in the L3 magnet of the ALICE experiment on the EMCal support structure described above. The super module will consist of a $12(\phi) \times 24(\eta)$ collection of modules spanning $0<\phi<\pi/9$ and $0<\eta<0.7$. With each module constructed of 2x2=4 towers, this super module provides 1152 towers.
- Readout electronics from the APD through to the interface to DAQ and trigger is provided for each tower.
- Trigger electronics for each 2x2 tower patch is provided.
- Each tower will have a cosmic ray pre calibration at the time of installation.

II.2 ALICE-USA EMCal Construction Project Scope

Following the R&D phase discussed above, a construction project will begin. The construction project is expected to proceed under the same management structure that governed the R&D phase. The construction project will complete the proposed detector acceptance with fully instrumented super modules.

Deliverables: (See Figure I.2)
Eleven ALICE-USA EMCal super modules delivered to CERN LHC point-2 and installed in the L3 magnet of the ALICE experiment on the EMCal support structure described above. These super module will each consist of a 12(ϕ) x 24(η) collection of modules and when installed in conjunction with the single super module produced under the R&D program, will provide a full detector spanning $0<\phi<2\pi/3$ and $-0.7<\eta<0.7$. With each module constructed of 2x2=4 towers, the full detector will have 13824 towers.

- Readout electronics developed under the R&D program and evaluated and tested in conjunction with the first super module from the APD through to the interface to DAQ is provided for each tower.
- Trigger electronics for each 2x2 tower patch is provided.
- Each tower will have a cosmic ray pre calibration at the time of installation.
- A minimum of two ALICE installation cycles will be provided for, one in FY08 and one in FY09.
- Software and hardware required to integrate the EMCal into the ALICE online and slow controls systems will be provided
- Sufficient reconstruction and offline software will be provided to finalize the calibration and fully establish the functionality of the detector.

III. MANAGEMENT ORGANIZATION

This section discusses the project management structure and practices governing detector design, fabrication and risk management.

III.1 Project Management responsibilities

This document provides the proposed management organization and delineates responsibilities within both the ALICE-USA R&D and construction the projects. Figure III.1 shows the management structure for both the ALICE-USA EMCal R&D and ALICE-USA EMCal construction projects.

III.1.1 Department of Energy

Within DOE's Office of Science (SC), the Office of Nuclear Physics (NP) has overall DOE responsibility for the ALICE-USA Electromagnetic Calorimeter (EMCal). The Acquisition Executive is Dennis Kovar, Associate Director of the Office of Science for Nuclear Physics (SC-90). Jehanne Simon-Gillo is the **EMCal Program Manager** in the Office of Nuclear Physics.

Responsibilities

The **EMCal Program Manager** responsibilities include:

- Provides programmatic direction for EMCal via the Federal Project Director.
- Functions as DOE headquarters point of contact for the MIE matters.
- Oversees MIE progress and help organize reviews as necessary.
- Budgets for funds to execute the MIE.
- Controls changes to MIE baselines in accordance with the PEP.

Barry Savnik has been assigned the **Federal Project Director** at the Berkeley Site Office (BSO).

Responsibilities

The **Federal Project Director** responsibilities include:

- Overall responsibility for planning, implementing, and completing EMCal.
- Provides overall MIE management oversight.
- Issues key work authorization.
- Provides necessary funds via approved financial plans.
- Manages contingency funds.
- Submits key project documents and critical decisions to DOE and report project progress.
- Ensures that the MIE complies with applicable ES&H requirements (e.g., National Environmental Policy Act [NEPA] requirements, California Environment Quality Act [CEQA], cryogen and electrical safety requirements, and radiation work authorizations).

III.1.2 Host Laboratory and Director of the Nuclear Science Division

Host Laboratory
The Host Laboratory is defined as the lead laboratory that is fully responsible for the construction of EMCal and assumes fiscal responsibility for the MIE. LBNL will be the Host Laboratory during the R&D, construction and test of EMCal and will be responsible for ensuring that the manpower and necessary infrastructure are provided.

Director of the Nuclear Science Division at LBNL
Funding for this project will be directed through the LBNL Nuclear Science Division. Thus, ultimate fiscal and management responsibility for the fabrication of EMCal will reside with the Director of the Nuclear Science Division, James Symons.

Responsibilities
The Director of the Nuclear Science Division at LBNL shall be administratively and fiscally responsible for the entire R&D effort and the MIE. In particular he/she must provide the following:

- Provides overall management oversight for all aspects of the MIE.
- Appoints the Contractor Project Manager.
- Approves key personnel appointments made by the Contractor Project Manager.
- Approves major subcontracts recommended by the Contractor Project Manager.
- Ensures that adequate staff and resources are available to complete EMCal in a timely and cost effective manner (within constraints of the budget provided by DOE).
- Ensures that EMCal has demonstrated that it meets the functional requirements.
- Provides documentation and access to information necessary for operation of EMCal at CERN.
- Ensures the work is performed safely and in compliance with the ISM rules.

III.1.3 Contractor Project Manager

The Director of the Nuclear Science Division at LBNL has appointed T.M.Cormier (WSU/LBNL) the EMCal Contract Project Manager.

Responsibilities:
The Contractor Project Manager shall report directly to the Director of the Nuclear Science Division at LBNL and will be in charge for the overall management of EMCal. The Contractor Project Manager shall appoint the key staff needed for the MIE with the approval of the Director of the Nuclear Science Division at LBNL. The Contractor Project Manager also will have the following responsibilities:

- Responsible and accountable for the successful execution of contractor's MIE scope of EMCal.
- Supports Federal Project Director in implementing DOE project management process.
- Provides input on project documentation.
- Implements contractor performance measurement system.

- Delivers project deliverables as defined in this management plan.
- Identifies and ensures timely resolution of critical issues within contractor's control.
- Responsible for EMCal functionality requirements
- Allocates the contingency funds according to the procedure defined in the Baseline Change Control Procedures (Section III.4).
- Acts as the spokesperson for the project to the DOE, the Host Laboratory, other ALICE-USA participating institutions, and the scientific community.
- Appoints the Deputy Contractor Project Manager with the approval of the Director of the Nuclear Science Division at LBNL.
- Collaborates with the Director of the Nuclear Science Division at LBNL and Deputy Contractor Project Manager to assemble the staff and resources needed to complete the project.
- Recommends to the Director of the Nuclear Science Division at LBNL, in consultation with the Deputy Contractor Project Manager, major subcontracts.
- Keeps the ALICE-USA Collaboration, ALICE Collaboration and general scientific community informed on the progress of the EMCal.
- Is the ALICE-USA representative to the ALICE Management Board
- Consults regularly with the ALICE-USA Collaboration on the development of the MIE.
- Appoints the Quality Assurance Manager (QAM) in consultation with the Deputy Contractor Project Manager.
- Defines the areas of collaboration and the relationship between LBNL and other institutions participating in EMCal through Memoranda of Understanding (MOU).
- Advises the Director of the Nuclear Science Division at LBNL on the selection of non-host-site construction teams, and of possible sub-contractors.
- Provides monthly input to Federal Project Director to be used in report to DOE.
- Submits quarterly status reports to BSO Federal Project Director.
- Ensures the work is performed safely and in compliance with the ISM rules.
- Produces necessary ES&H documentation (e.g., NEPA and CEQA).

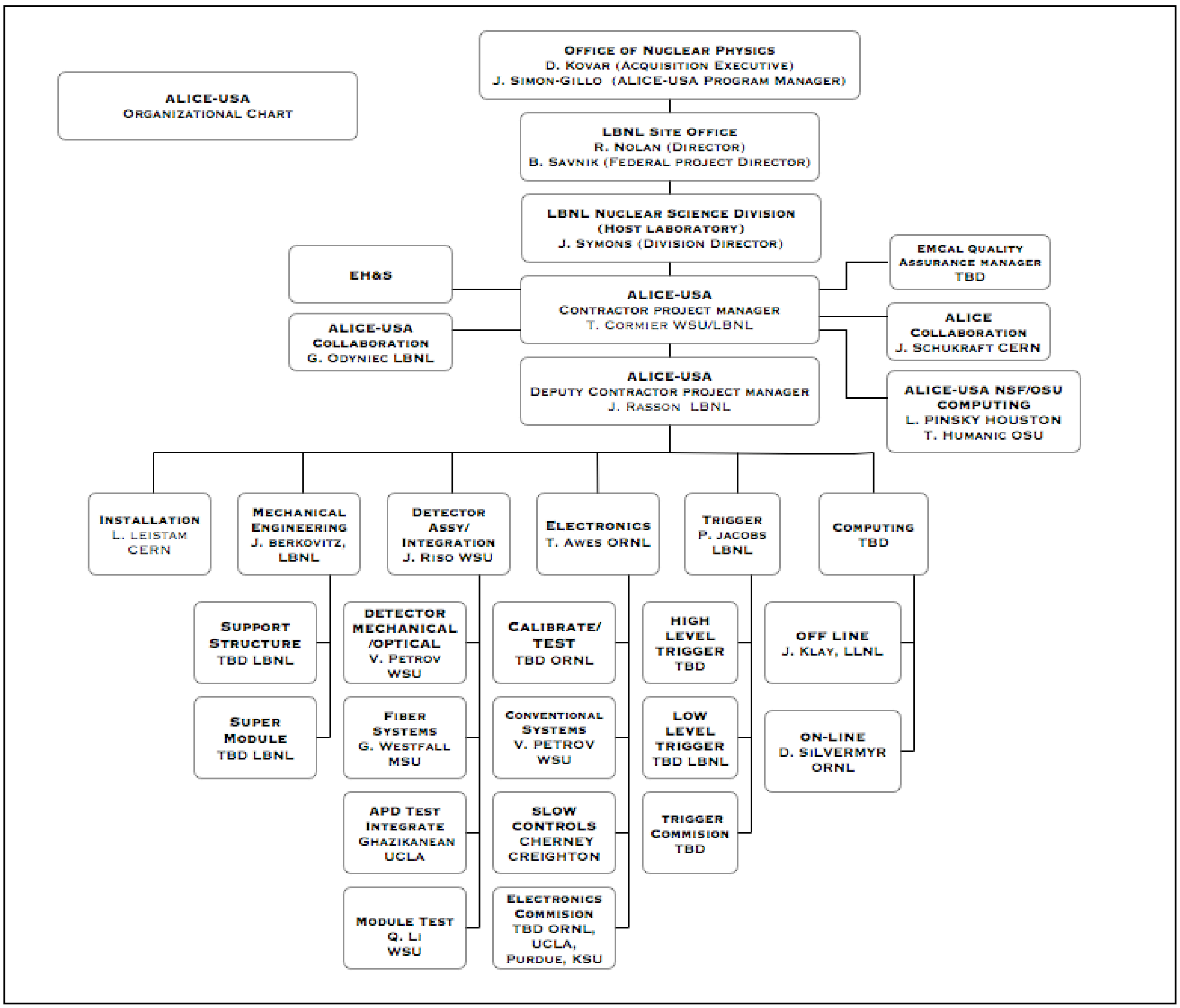
III.1.4 Deputy Contractor Project Manager

The EMCal Contractor Project Manager, with the approval of the Director of the Nuclear Science Division at LBNL, has appointed J. Rasson (LBNL) the EMCal Deputy Contractor Project Manager. The Deputy Contractor Project Manager will report to the Contractor Project Manager.

Responsibilities

- Under the direction of the Contractor Project Manager executes contractor's MIE scope of EMCal, and supplies the deliverables on time and within budget.
- Collaborates with the Director of the Nuclear Science Division at LBNL and Contractor Project Manager to assemble the staff and resources needed to complete EMCal.
- Communicates the functional requirements to the subsystem managers.

- Responsible along with the Contractor Program Manager for the technical direction of EMCal.
- Responsible for the development of the EMCal system design requirements, including interfaces between subsystems, and achieving these requirements.
- Controls changes in the EMCal system design requirements, including interfaces between subsystems.
- Responsible for developing and maintaining the EMCal documentation.
- Supervises the LBNL staff of the EMCal project.
- Oversees the effort from other institutions participating in EMCal.
- Identifies and ensures timely resolution of critical issues within Deputy Contractor Project Manager's control.
- Identifies and manages project risks.
- Carries out monthly project review and reports results to the Contractor Project Manager.
- Coordinates preparation of regular reports and project reviews as required by DOE and LBNL.
- Ensures the work is performed safely and in compliance with the ISM rules.



- Provides regular reports on the status of the subsystem to the Deputy Contractor Project Manager.
- Ensures the work is performed safely and in compliance with the ISM rules.

III.1.6 Collaboration Liaisons

Liaisons to the ALICE and ALICE-USA collaborations advise the Contractor Project Manager regarding the interests of these collaborations as the detector design and construction goes forward. In particular, they will lead the establishment, review and collaboration approval of the physics requirement document and participate in the development of the corresponding functionality requirements. The collaboration liaisons sit on the change control board and are responsible to monitor and assess the impact on the physics requirements, of any and all changes in functionality that might be introduced through the change control process. The ALICE-USA Collaboration Liaison is Grazyna Odyniec (LBNL) and the ALICE Collaboration Liaison is Jurgen Schukraft (CERN).

III.1.7 Quality Assurance Manager (QAM)

The Contractor Project Manager will assign the Deputy Contractor Project Manager, one of the Subsystem Managers, or another person involved in the project to assume the additional role of QAM.

Responsibilities

- Collaborates with the Contractor Project Manager and Deputy Contractor Project Manager to ensure the quality of EMCal.
- Ensures that the quality control system is established, implemented, and maintained in accordance with the EMCal Quality Assurance Plan.
- Provides oversight and support to the partner labs and institutions to ensure a consistent quality program.

III.1.8 Integrated Project Team

The composition of the GRETINA Integrated Project Team (IPT) is given in Table . Its responsibilities are described in the DOE directive. The team will meet at least quarterly, or more frequently if necessary. The DOE Federal Project Director will chair the IPT.

Table III.2. ALICE-USA EMCal Integrated Project Team

DOE Federal Project Director	Barry Savnik (chair)
DOE Program Manager	Jehanne Simon-Gillo
LBNL Contractor Project Manager	T. Cormier
LBNL Deputy Contractor Project Manager	J. Rasson
DOE Contracting Officer	TBD
LBNL Contracting Officer	TBD
DOE ES&H Lead	TBD
LBNL EH&S Lead	TBD

III.2 Risk Management and Baseline Change Control Plan

III.2.1 Risk Management

Risk, as applied in the context of this project, refers to events that might negatively impact cost, schedule, technical performance or programmatic performance of the ALICE-USA Electromagnetic Calorimeter (EMCal). The EMCal Contractor Program Manager implements risk management practices as outlined below:

III.2.1.1 <u>Pre Construction Risk Mitigation:</u> Pre construction risk management focus on establishing a project design and scope baseline adequate to minimize probability of technical or programmatic failure. Through a series of R&D studies and peer reviews the design and scope are validated and a cost and schedule baselines are established.

- **Requirements Review:** The ALICE-USA spokesperson will organize a review of the EMCal Requirements Document. This document presents minimum but sufficient physics design parameters necessary to meet both technical and programmatic performance requirements. This document is included in this management plan as Appendix A.

- **Conceptual Design Review:** The ALICE-USA spokesperson will organize a review of the EMC collaboration's Conceptual Design Report. This constitutes the first complete statement of the scope consistent with the Requirements Document. As such, this review mitigates, among other things, risk associated with technical performance.

- **Internal Technical Subsystem Design Reviews:** Reviews, organized by the project manager, will be conducted internally within the EMCal project to track and validate subsystem design consistent with overall detector functionality requirements.

- **Final Design Review:** The ALICE-USA spokesperson and ALICE spokesperson will jointly organize a review of the EMCal's validated final design. This is largely a technical review to establish the project engineering change control baseline and provide the basis for the development of the construction project cost and schedule.

- **Cost and Schedule Review:** The deputy project manager will organize an external review of the EMCal's cost and schedule. This review examines the project cost, contingency analysis and schedule prior to formal project proposal. TEC Contingency analysis is an integral part of the risk management plan and is discussed in section IV below.

III.2.1.2 Construction Phase Risk Mitigation: Construction phase risk management focuses on minimizing the probability of cost and schedule failure.

- **Annual Technical Advisory Committee Review:** The program manager will organize an annual review of the project by a team of external experts which focuses on cost and schedule. These reviews allow a systematic tracking of cost and schedule that provide an important mechanism to provide early risk identification, quantification and handling along with external evaluation of impact.

- **Change Control Process:** We distinguish two classes of change control: Engineering Change Control and Budgetary or Cost and Schedule Change Control, which are discussed separately below.

- **Quarterly DOE Cost and Schedule:** The EMCal project prepares quarterly progress/cost and schedule reports for DOE review.

- **Quarterly Internal QA/QC Review:** During construction, the EMCal project management board continuously monitors QA/QC data at the subsystem level to ensure uniform detector quality across the extended construction period. This is done to minimize the risk of technical or programmatic failure.

- **Engineering Change Control:** Under precisely defined circumstances, we will allow experience from the "factory floor" to influence production and assembly methodologies. Post Final Design review, only EMCal production drawings are valid for component fabrication or system assembly. Requests for changes in production drawings may originate with the Subsystem Managers. The Project Manager reviews engineering change requests for cost and schedule impact, consistency with the EMCal Requirements Document and consistency with ALICE integration requirements. Change requests which, in the project manager's view result in cost reduction or schedule improvement and sufficiently enhance the probability of technical or programmatic success are submitted to the committee of subsystem managers for review. The project manager chairs this review. Technically validated requests may be approved by the committee of subsystem managers if there is no budgetary impact.

- **Cost, Schedule and Performance Change Control:** A formal Change Control System has been established that defines and documents the process for changes and control of cost, performance and schedule baselines. Contingency funds are included in the EMCal project cost estimate to cover uncertainties and risks. Although risk based contingency is estimated on the subsystem level it does not belong to a specific subsystem. Rather, guidelines for assigning contingency are established by the project director under this management plan and follow standard DOE practices http://www.sc.doe.gov/sc-80/sc-81/practices.html

During project execution, the documented change control process is used to move contingency to the base budget without increasing the TEC in response to:

1. Material and labor cost variance that exceed the change control threshold in any WBS category (see below)
2. Threats to schedule or technical performance that will significantly impact programmatic performance.(see below)

Below the change control threshold, subsystem managers are directed to first attempt to compensate for cost variances within the annual subsystem budget. Failing this, or in the case of cost variances over threshold or of significant threats to schedule, a formal change request is submitted by the subsystem manager to the project manager. The project manager in consultation with the deputy project manager and the committee of subsystem managers may approve movement of contingency in cases where the required contingency does not significantly exceed the estimated TEC Contingency[2] for the particular WBS category.

In the event that the required contingency exceeds the estimated TEC contingency for the particular WBS category the level of approval required and the reporting requirements are presented in table III.4.1 for four different varying categories of cost, schedule or performance impact. In the event of a category 4 threat to cost, schedule or performance, a project wide reevaluation of contingency reserves will be conducted using documented TEC contingency estimating algorithms (see below). This is done to ascertain the potential impact of the requested contingency on the probability of cost or schedule failure for the balance of the project. The results of this analysis are reported to the DOE.

III.4.3 Performance and Schedule Control

III.4.3.1 Performance Control

The basis for performance control is in the table of Change Request Classifications Table III.4.1. This specifies the approval levels required to authorize a change in performance or scope of the experiment depending on the expected impact of the change.

III.4.3.2 Schedule control

[2] TEC Contingency accounts for cost estimating uncertainties associated with hardware design, procurement, construction, installation and commissioning costs.

The basis for schedule control is the summary milestone schedules contained in this document in section IV. Detailed schedule tracking and reporting will be done by the project director team down to WBS Level 4 and routinely reported to WBS 3 as part of the quarterly reporting structure. Schedule tracking below WBS level 4 is the responsibility of the subsystem managers and is routinely reported only to the Project Management.

Table III.2.1 Change control category versus the level of approval required and the reporting requirements

	Cost	Schedule	Performance	Approval	Reporting
1	Minor, within WBS line item and <$10k	"float"	No impact	Subsystem Manager	Project Manager
2	Within subsystem contingency allocation and >$10k	<1 Quarter delay of milestone	Sub-subsystem change not affecting subsystem performance or scope	Above plus Project Manager	Above plus ALICE-USA Management
3	Within overall project contingency and >$30k	> 1 Quarter delay of milestone	Subsystem change affecting subsystem performance but not EMC performance	Above plus ALICE-USA management	Above plus Agency
4	Within overall project contingency and >$100k	> 1 Quarter delay of milestone impacting installation goals	Technical scope change, affects experiment capability	Above plus Agency	

IV. Cost and Schedule

IV.1 Overview of Project Costs

The cost roll up to WBS level 1 and funding profile for the proposed R&D is given below in table IV.1.

The costs shown here take advantage of institutional contributions applicable to FY05 and FY06. These institutional contributions are above and beyond contributions from the base program which are very substantial but are not accounted for explicitly in the WBS. The institutional contributions secured to date in FY05 and 06 are outlined in table IV.2

Table IV.1. Level 1 WBS for the proposed R&D scope with the incremental costs per super module in the out years also indicated (Construction Phase)

	B	C	X	AC	AD	AE	AF	AG	BH	BM
2–4		Version 1.7 6-29-05	R&D Phase FY05 to FY08						Construction Phase approximate incremental cost per super module	
5–6	WBS Number	WBS Name	Total Contingency	Total Project Cost	FY05 Cost	FY06 Cost	FY07 Cost	FY08 Costs	Total Contingency	Total Project Cost
7	1	ALICE-USA EMCAL	$555,182	$4,245,969	$169,434	$1,132,536	$2,515,065	$428,935	$116,677	$775,481
9	1.1	Detector Prototype	$40,622	$136,906	$324	$136,581	$0		$0	$0
70	1.2	EMCal Integration	$24,323	$286,997	$34,812	$176,464	$75,721	$0	$0	$0
83	1.3	Process Engineering	$58,456	$338,816	$0	$180,671	$158,145		$0	$0
144	1.4	EMCal Support Structure	$159,071	$1,066,500	$63,036	$223,582	$779,883		$0	$0
175	1.5	Super Module	$204,814	$1,026,150	$0	$0	$946,623	$79,528	$72,589	$376,443
239	1.6	Module and Component Test	$11,571	$53,865	$0	$0	$53,865	$0	$3,981	$20,216
245	1.7	Electronics	$26,131	$198,409	$0	$0	$0	$198,409	$26,131	$198,409
266	1.8	EMCal Software	$0	$0	$0	$0	$0		$0	$0
278	1.9	EMC Conv. Sys.	$9,874	$76,777	$0	$0	$76,777	$0	$4,648	$28,254
289	1.10	Project Management and Integration	$20,320	$1,061,548	$71,262	$415,238	$424,052	$150,997	$1,446	$73,340
301										
302	1.11	Computing		$0	$0	$0	$0	$0	$7,882	$78,818
303										

The total credit taken in the Project WBS (Table IV.1) is $287k. Additional institutional contributions are pending in FY06 and beyond but they cannot be guaranteed at this time.

Table IV.2. FY05 and FY06 Institutional Contributions

Institution	Amount	Scope	WBS
ORNL	$125k	Electronics R&D	1.7.1.19
WSU	$120k	Detector Prototype	1.1.5
WSU	$ 42k	Integration	1.2.1 and 1.2.2

The full scope of the proposed R&D is accomplished on schedule for the following funding profile:

FY05:	$ 164k (Q4)
FY06:	$ 1092k
FY07:	$ 2494k
FY08:	$ 424k (Q1)

R&D TPC:	$ 4246k

In addition, we show in table IV.1 that the incremental costs per super module is $775k in the out years leading to a TPC for the construction phase of $8525k. For the full project scope of 12 installed and instrumented super modules, the TPC is $12,771k. The optimum funding profile for completing the R&D and the full construction scope is given in table IV.3.

Table IV.3. Optimum funding profile for the full R&D plus construction scope

R&D					
FY05	FY06	FY07	FY08		
$169	$1,133	$2,515	$429		
			Construction		
			FY08	FY09	FY10
			$3,100	$3,100	$2,325

The full WBS for the R&D phase of the project along with the costs per super module in the construction phase is given in appendix C.

IV.2 TEC Contingency Analysis

Contingency funds are included within the ALICE-USA EMCal cost estimate to cover uncertainties in materials, labor, and other conditions and risks which are an intrinsic part of the intended scope of work, but are not specifically allowed for elsewhere in the estimate. Funds reserved as contingency do not appear in the base of the WBS due to uncertainty either as to their existence, nature, likelihood of occurrence, or magnitude of effect. Since contingency is not assigned to specific elements of the WBS, it is therefore not considered part of the Performance Measurement Baseline. All changes from baseline costs are traceable under change control (as described above) so that contingency applications can be tracked.

The TEC contingency will be established here, at the outset of the EMCal project, using a risk based analysis identical to that used for the STAR project. This same analysis will be repeated annually to validate the contingency reserve as a function of the estimated base cost to completion and potentially varying cost and schedule risk. Generally, as the design and the prototyping phase of the project is completed and routine procurement dominates, the remaining cost and schedule risk is correspondingly reduced. In practice, however, this may not be the case and periodic reexamination of the risk analysis will thus be undertaken.

The TEC Contingency analysis used here begins by defining a four dimensional Risk vector with Technical, Design, Cost and Schedule components, R_i i =1,2,3,4. Standard values are assigned to each of these components on the scale of 0 to 15 depending on the risk category applied to each element of the WBS at its lowest level. For example, the Technical risk factor varies from 1 for the category "existing design and off shelf hardware" to 15 for "new design well beyond state-of-the-art". A weight vector is similarly defined with the same components as the risk vector but with component values W_i of 1 through 4 scaling from single to multiple risk associated with a given element. For example, the Cost weight factor varies from 1 to 2 as either or both labor and material costs contribute to the risk.

Table IV.4 Risk vector components by risk category.

TECHNICAL, COST, & SCHEDULE RISK FACTORS

Risk Factor	Technical	Design	Cost	Schedules
0	Not used	Detail design > 50% done	Not used	Not used
1	Existing design and off the shelf H/W	Not used	Off the shelf	Not used
2	Minor mods to a existing design	Not used	Vendor quote from established drawings	Not schedule impact on any other items
3	Extensive mods to an existing design	Not used	vendor quote with some design sketches	Not used
4	New design, nothing exotic	Preliminary design >50% done; some analysis done	In-house estimate based on previous similar experience	Delays completion of of critical sub-system item
6	New design; nothing exotic	Not used	In-house estimate for item with minimal experience but related to existing capabilities	Not used
8	New design requires some R&D but does not advance the state-of-the-art	Conceptual design phase, some drawings; many sketches	In-house estimate for item with minimal in-house capability	Delay completion of critical sub-system
10	New design; of new technology; advances state-of-the-art	Not used	Top-down estimate from analogous programs	Not used
15	New design well beyond current state-of-the-art	Concept only	Engineering judgment	Not used

The scalar product of the Risk and Weight vectors, $\sum W_i R_i$, defines the WBS category contingency in percent as applied to the corresponding base cost. The risk factors and weight factors used in our analysis are listed in tables IV.4 and IV.5 respectively.

The contingency analysis procedures described here are used both to establish the required contingency at initial TEC formulation and to track changing contingency needs throughout the project as risk levels associated with various aspects of the scope change.

TECHNICAL, DESIGN, COST & SCHEDULE WEIGHTING FACTORS

	Condition	Weighting Factor
Technical	Design OR Manufacturing	2
	Design AND Manufacturing	4
Design	Same for all	1
Cost	Material Cost OR Labor Rate	1
	Material Cost AND Labor Rate	2
Schedule	Same for all	1

Table IV.5 Weight vector components by risk

IV.3 Schedule and Summary Milestones

Figure IV.1 shows the schedule for the R&D phase of the project to WBS level 3. Four critical milestones are indicated as red circles:

1. Test Beam completed 1/03/06. The 64 tower prototype with its readout electronics has been integrated and a test beam run has been completed which has satisfied the critical goals for that measurement.

2. Support Structure Installed 8/25/06. The integration, design, fabrication and installation of the EMCal support structure has been installed in ALICE.

3. Super Module Installed 8/24/07. The super module design, fabrication and testing has been completed and the module is successfully installed in ALICE

4. Detector Ready 10/15/07. The installed super module has been fully instrumented with readout and trigger electronics; conventional systems are functional and the module is operating under slow controls and DAQ controls. Online software including detector monitoring is functional and offline software is functional at the level required for detector calibration and rudimentary analysis.

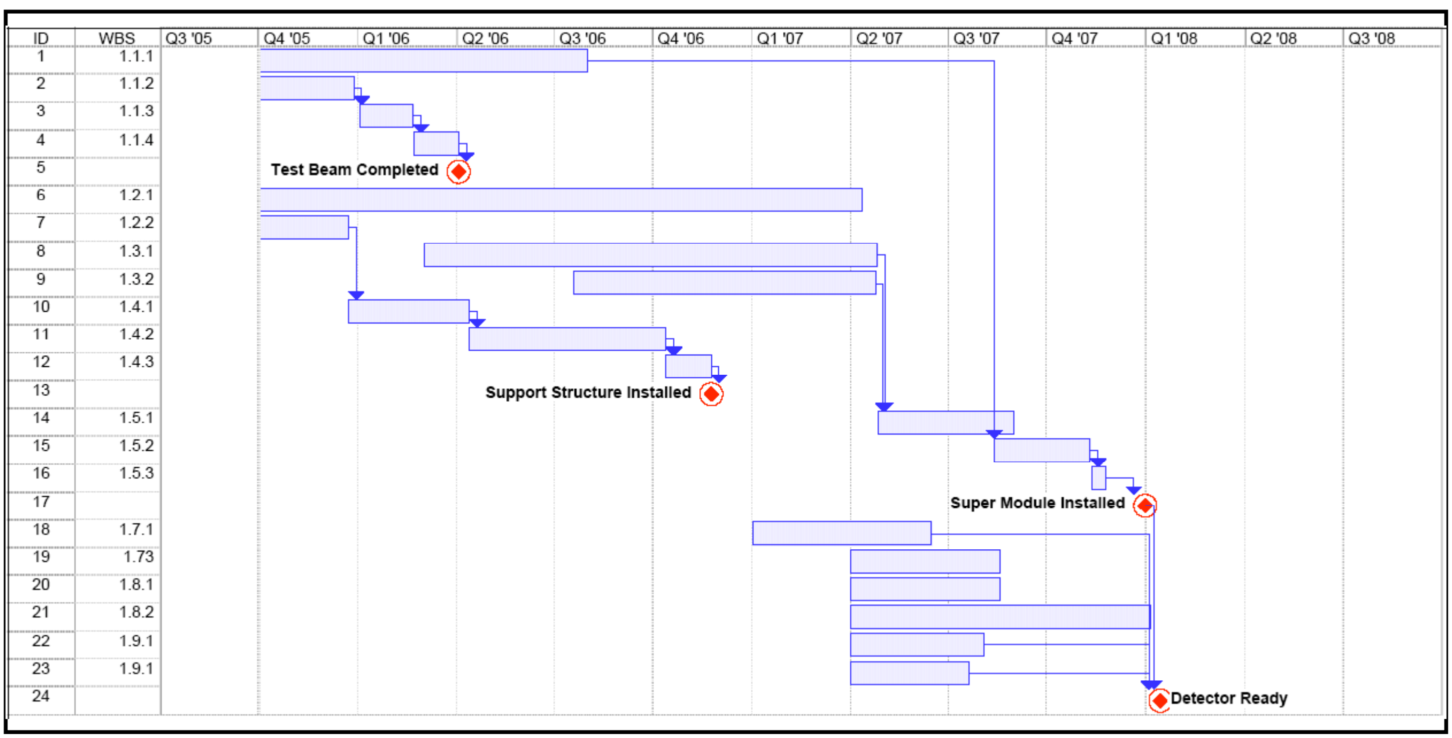


Figure IV.1 EMCal R&D schedule to WBS level 3.

WBS	Description	Milestone
1.1.1	Mechanical Analysis/Prototypes	05/01/06
1.1.2	Tower Optical Studies	09/27/05
1.1.3	Prototype Construction	11/21/05
1.1.4	Prototype Test Beam	01/02/06
	Critical Milestone: Test Beam Completed	**01/03/06**
1.2.1	EMCal Detector Integration	01/11/07
1.2.2	Pre-CDR/TDR Work	09/22/05
1.3.1	Injection Molded Parts	01/25/07
1.3.2	Laser cut parts	01/23/07
1.4.1	EMCal Support Structure Design	01/12/06
1.4.2	Module Support Structure Procurement	07/13/06
1.4.3	Module Support Structure Installation	08/24/06
	Critical Milestone: Support Structure Installed	**08/24/06**
1.5.1	Parts and Components	05/31/07
1.5.2	Assembly	08/10/07
1.5.3	Installation	08/24/07
	Critical Milestone: Super Module Installed	**08/24/07**
1.7.1	Electronics	03/16/07
1.73	Test Calibrate	05/18/07
1.8.1	OnLine	05/18/07
1.8.2	OffLine	10/05/07
1.9.1	Conventional Sys. Cooling	05/04/07
1.9.1	Conventional Sys. LV Power	04/20/07
	Critical Milestone: Super Module Ready	**10/15/07**

Appendix A ALICE EMCAL REQUIREMENTS DOCUMENT

1 . INTRODUCTION

The Large Hadron Collider (LHC) will allow the study of Pb+Pb, p+A, and p+p collisions at center of mass energies of up to 14 TeV for p+p collisions, and up to 5.5 A GeV for Pb+Pb collisions. The ALICE detector is one of three large detector facilities at the LHC. It is unique in that it was specifically designed for the LHC Heavy Ion program to take full advantage of the enormous range of physics observables. ALICE will play the leading role in the study of Pb+Pb collisions and will provide unique measurement capabilities for p+A and p+p collisions. An important subset of these physics opportunities, ranging from the gluon structure functions of heavy nuclei at very low Feynman-x to parton energy loss in the quark gluon plasma, require a large solid angle electromagnetic calorimeter to complement the tracking and particle identification of the ALICE Time Projection Chamber (TPC) and related systems.

The purpose of the present document is to convey the design requirements of the ALICE Electromagnetic Calorimeter (EMCal) and to justify those requirements in terms of their relation to the proposed physics program and realistic budgetary constraints. It is beyond the scope of the present document, however, to attempt to justify the proposed physics program. In the following, therefore, we will merely mention physics topics in passing where required and assume that the reader is knowledgeable concerning the significance of cited physics topics to the entire LHC program.

2 . EXECUTIVE SUMMARY

2.1 Summary Description

The main physics goal of the EMCal is the study of jet modification in dense matter (“jet quenching”), which will play a central role in the LHC Heavy Ion program. The rate of jets in the nominal EMCal acceptance is large, with about 500K jets with energy exceeding 100 GeV expected in the EMCal trigger acceptance per LHC heavy ion running period. Full understanding of jet quenching requires reconstruction of jet fragments over a broad kinematic range, including very soft fragments. The EMCal combined with the excellent tracking and PID capabilities of ALICE in the heavy ion collision environment enables such detailed studies for jets ranging in energy from those accessible at RHIC, where quenching effects are large, to well beyond 100 GeV, where quenching effects are expected to be small.

The EMCal aims to provide large acceptance coverage at a low cost. The emphasis on high p_T means that the intrinsic energy resolution of the EMCal can be modest and the detector granularity can be coarser with moderately high occupancy as compared to PHOS, the other electromagnetic calorimeter of ALICE that emphasizes the low p_T measurement, with high resolution but limited acceptance. These design criteria point toward the choice of a sampling calorimeter design, similar to those built for PHENIX and STAR at RHIC.

The overall design of the EMCal is heavily influenced by its location within the ALICE L3 magnet. The EMCal is to be located inside the large room temperature magnet within a cylindrical integration volume approximately 108cm deep, by 7.0m in length, sandwiched between the ALICE TPC space frame and the magnet coils. Due to the installation of the PHOS carriage below the ALICE TPC and the HMPID above the ALICE TPC, the EMCal is limited to a region of about 120 degrees in azimuth above the TPC adjacent to the HMPID. In the present discussion, this is the extent of the proposed EMCal. Space for future expansion following the removal of the HMPID after two or three LHC runs and space adjacent to the PHOS could be utilized in the future to create nearly complete EMCal azimuthal coverage at some future date should the need arise.

The chosen technology is a layered Pb-scintillator sampling calorimeter with a longitudinal pitch of 1.6mm Pb and 1.6mm scintillator. The full detector spans $\eta = -0.7$ to $\eta = 0.7$ with an azimuthal acceptance of $\Delta\phi = 120^o$. The readout of the scintillator is of the “Shishkabob” or “Shashlik” type similar to the PHENIX Pb-scintillator sampling calorimeter[3] in which the scintillation light is collected via wavelength shifting fibers (WLS) running through the Pb-scintillator tiles perpendicular to the front surface. The detector is segmented into ~13,824 towers, each of which is approximately projective in η and ϕ to the interaction vertex.

The basic structural units of the calorimeter are supermodules, each subtending approximately ~20° in $\Delta\phi$ and 0.7 units in $\Delta\eta$. Supermodules are assembled from individual modules. The modules are further segmented into 2x2 individually read out towers. The supermodules weigh about 9.6 tons and are the basic units handled during installation. Each supermodule is roughly 145cm wide at the front surface by 350cm long with an active depth of 24.8cm (at η=0). The physical characteristics of the EMCal are summarized in Table 2.1.

The EMCal is a fast detector that provides unique event selectivity for hard processes early in the trigger decision logic (trigger levels 0 and 1), thereby enhancing significantly the physics recorded by the ALICE detector. The EMCal provides an efficient trigger for jets and high transverse momentum π^0, γ and electrons at Trigger Level 1 for heavy ion collisions and Trigger Level 0 for p+p collisions. Beyond the trigger, the EMCal provides crucial input to many aspects of the ALICE physics program.

The EMCal provides:

- Single Shower Triggers for measurement of:
    - π^0 and η production: leading hadrons of jets

[3] L. Aphecetche et al. (PHENIX), Nucl. Instrum. Meth**. A499**, 521 (2003).

  - o Direct photon production: γ+jet coincidences for jet quenching studies, gluon structure functions, etc.
  - o Inclusive electrons: heavy quark production, heavy quark jet tagging
- Patch Triggers for measurement of jet production

Due to the location of the EMCal within the ALICE magnetic field, the signals from the EMCal are read out with Avalanche PhotoDiodes (APDs), as is the PHOS. Also, since the light output/MeV of energy deposit in the EMCal is similar to that of PHOS and their performance requirements are similar, the EMCal readout follows closely the PHOS readout and uses the same readout elements whenever possible. The EMCal readout parameters are summarized in Table 2.3. The APDs will be operated at a gain of about 50. The APD output is integrated with a Charge Sensitive Preamplifier (CSP) attached to the APD on the EMCal module. The CSP output is processed by dual CR-2RC shapers having gains differing by a factor of 16 and with a peaking time of 200ns. The shaped output signals are digitized with 10-bits resolution at 20Mhz. When the event trigger is received, the 20-samples wide region of digitized energy signals corresponding to the physics event is transferred to local memory in the FEE. Up to 8 events may be buffered locally in the FEE. The data is readout of the FEE over a 40-bit wide bus at 60MHz. The digitized pulse shape of the signal is analyzed offline to extract arrival the signal arrival time with a time resolution adequate (~1ns) for rejection by time-of-flight of slow neutrons and anti-neutrons.

In parallel with the data path to the DAQ, the Front End Electronics (FEE) will provide a fast energy signal path with a reduced resolution for trigger purposes. Trigger primitives of adjacent 2x2 tower sums are digitized with 8 bits of resolution and passed to Trigger Region Unit (TRU) modules to form digital sums of the 2x2 trigger primitives over larger EMCal regions. Sums of overlapping regions of 4x4 towers will be made to provide single shower (photons or merger π^0's). Sums of 2x2 tower sums over much larger patch regions will be used to provide jet trigger information.

As an ALICE detector subsystem, the EMCal adheres to all of ALICE's existing interface standards and specifications for slow controls, trigger, on-line and DAQ.

2 . 2 Table of EMCal Mechanical Parameters

Quantity	Value
Sampling Ratio, d_{Pb}/d_{Sc}	1.6 mm Pb / 1.6mm Scintillator
Sampling Fraction, $f_s=\Delta E_{Sc}/\Delta E_{Pb}$	0.0811 (including all ALICE materials)
Energy Resolution	12% / $\sqrt{E}$
Calibration	LED, π^0's, electrons
Total depth	24.8 cm
Number of Pb/Sc layers	78
Number of Radiation Lengths	22.3 (active detector only)
Module Size	12.7 X 12.6 X 31 cm^3
Tower Size (at η=0)	$\Delta\phi \times \Delta\eta$ = 0.015 x 0.015
Occupancy ($dN_{ch}/d\eta$=2500)	Hit:16% Tower:~80%
Number of Towers	2x2=13,284
Number of Modules	12x12x24=3456
Number of Supermodules	12
Weight of Supermodule	~9.6 tons
Total Coverage	$\Delta\phi$ =120^o, $-0.7 < \eta < 0.7$

2 . 3 Table of EMCal Readout Parameters

Quantity	Value
Digitization Ranges 10bit x16 and x1 ranges; 14bits effective	HiGain: 16MeV-16GeV LoGain: 250MeV-250GeV LSB=16MeV
Light Yield	2.5 e-/MeV at M=1; 125e-/MeV at M=50
Channel rate at E>30 MeV	2kHz
APD	e.g. Hamamtsu S8664-55 (5x5mm^2); C_{APD}=90pF; Excess noise factor F=3.6; Dark current ~10nA
Charge Senstive Preamp (PHOS)	JFET:2SK932; C_{in}=10pF; 60mW; 0.78mV/fC or 0.128μV/e-
CSP Output range	0.45mV-4V (16MeV-250GeV)
Electronic Noise Charge (ENC)	1500e- (~12MeV)
Shaper (PHOS)	CR-2RD type; Semi-Gauss; τ_{int} = 100ns; τ_{peak} = 200ns
Fast OR signal shaping	FWHM=100ns
Timing Resolution	~1 ns
Trigger	LVL0(<800ns)=Shower: LVL1(<6μs)=Shower, Patch
ADC	ALTRO-16ST, 16*10bit@20/40MHz,LSB_{noise}<0.5mV Effective Number of Bits (ENOB) = 9.5
Sampling Rate: $1/\Delta t$	20MHz
Max.Nr.Samples/Signal ($5*\tau_{peak}/\Delta t$)	20
Data rate per channel	2kHz*(2 range)*(20 samples)*(10bits)=100kByte/s
Power consumption	<400mW/channel

3. DETECTOR REQUIREMENTS

3 . 1 System Functionality

Requirement:

There shall be a sampling electromagnetic calorimeter in ALICE with coverage of 120^0 in ϕ and –0.7 to +0.7 in η. Dead areas shall be minimized relative to the Moliere radius of an electromagnetic shower (~2cm) and to the size of a hadronic jet.

Justification:

Jet cross sections fall rapidly with increasing energy, and large acceptance is desirable to give adequate coverage for high energy jets. Jets are extended objects, typically filling a cone radius $R=(\Delta\eta^2+\Delta\phi^2)^{1/2}$~0.7, though in central heavy ion collisions the underlying event is indistinguishable from the tails of the jet and smaller cone radii (R~0.3) must be used to preserve reasonable jet energy resolution.

The EMCal presently uses all available space in ALICE since the space is limited in ϕ by other ALICE detectors (PHOS and HMPID) and limited in Z to the length of the ALICE TPC. A minimum acceptance of

–0.7 to +0.7 in η is required to provide sufficient rate of jets and photons for detailed study of jet quenching over the full range of interest, out to high energy where quenching effects are expected to be small. Jet reconstruction requires fiducial cuts far from detector edges, which would severely limit the acceptance for a smaller detector. The large acceptance is also needed to cover a broad x range for measurement of gluon distributions in p+Pb and p+p collisions. Within this coverage, dead areas of the scale of the observable, electromagnetic or hadronic showers, have an unacceptable impact on the detectors acceptance since each dead area nominally requires a fiducial cut of comparable size.

3 . 1 . 1 Measurement Functionality

Requirement:

The EMCal must enable the detection of photons and reconstruction of π^o's (and η's) above approximately 1 GeV/c in the Pb+Pb environment to cover the full transverse momentum range from the thermal region of the spectra to the high p_T region where hard scattering and jet fragmentation dominate the production. The direct photon, π^o, and jet measurements in p+p and p+A provide essential control measurements needed to understand jet modifications in A+A collisions, and enable measurement of the gluon structure functions in heavy nuclei over a very broad range in x.

Together with the ALICE TPC, TRD, and Inner Tracking System, the EMCal will trigger on and measure electrons from open charm and bottom production. Electron pairs will also be measured, giving access to color screening effects in the plasma via modification of quarkonium production.

Justification:

These observables cover a large part of the physics program envisioned for LHC addressable via electromagnetic measurements.

3 . 2 CALORIMETER CHARACTERISTICS

3 . 2 . 1 Energy Resolution

Requirement:

The electromagnetic energy resolution, defined as the Gaussian sigma divided by the mean, shall be better than required to satisfy the measurement functionality.

Justification:

The measurement functionality of section 3.1.1 is a requirement. Monte Carlo studies show that a resolution better than or equal to 15%/E[GeV] at energies above 300 MeV satisfies the measurement functionality of section 3.1.1.

For example:

- In the measurement of the direct γ and pion production this resolution is adequate.
- At the high energy end, where we use the energy in the calorimeter vs. the momentum from the TPC to identify electrons, this energy resolution is better than the momentum resolution from TPC plus vertex.
- For direct-γ+jet studies to measure the gluon structure function, this resolution on the γ is better than the resolution possible for the jet.

3 . 2 . 2 Spatial Resolution

Requirement:

The EMCal tower size shall be small enough to reduce combinatorial problems (average occupancy <1) in resolving multiple γs in p+p and identifying photons and electrons in Pb+Pb events. For cost reasons, we want the cell size as large as consistent with the physics.

Justification:

A calorimeter segmentation of 0.015 x 0.015 gives about 80% tower occupancy in Monte Carlo studies of central Pb+Pb events. Identification of photons and electrons in Pb+Pb events will be limited by overlapping background in the towers from hadrons and photons. The higher the average energy associated with this background the higher the minimum p_T at which electrons and photons can be isolated. A calorimeter segmentation of 0.015 x 0.015 gives an acceptable background energy per tower in Monte Carlo studies. The tower segmentation also imposes an upper p_T limit above which photons from π^0 decay fall within a single tower and will be misidentified as a photon rather than as a π^0.

3 . 2 . 3 Solid Angle Coverage

Requirement:

The device will subtend 120^0 in ϕ and –0.7 to +0.7 in η with inactive regions that do not compromise the electromagnetic energy measurement or jet reconstruction capabilities.

Justification:

The EMCal presently uses all available space in ALICE since the space is limited in ϕ by other ALICE detectors (PHOS and HMPID) and limited in Z to the length of the ALICE TPC. A minimum acceptance of –0.7 to +0.7 in η is required to provide sufficient rate of jets and photons for detailed study of jet quenching over the full range of interest, out to high energy where quenching effects are expected to be small. Jet reconstruction requires fiducial cuts far from detector edges, which would severely limit the acceptance for a smaller detector. The large acceptance is also needed to cover a broad x range for measurement of gluon distributions in p+Pb and p+p collisions.

4. EMCAL ELECTRONICS

4 . 1 APD Signal Shaping

Requirement:

The integration and shaping time of the preamplier/shaper of the APD signal shall be chosen to keep the electronics noise contribution to the total energy resolution negligible in comparison to other contributors to the resolution.

Justification:

Electronics noise contributions should not degrade the calorimeter performance since they can be minimized with suitably chosen signal shaping time. A shorter than optimal shaping time from an electronics noise point of view may be chosen to minimize contributions from event pileup and background neutrons.

4 . 2 Dynamic Range of Calorimeter Energy Measurement

Requirement:

The dynamic range of the calorimeter must adequate to measure soft π^0 photons and electrons in the Pb+Pb and p+p programs.

Justification:

The EMCal energy scale must encompass the full scope of the ALICE physics program. The low energy end of the dynamic range is specified by the need to measure the soft photons from π^0 background to extract the direct γ yield and to reconstruct low p_T π^0's in the Pb+Pb program. The high end of the range is fixed at about 250 GeV by the need to measure energetic π^0's from the highest energy jets. A dynamic range of 14-bits of effective (dual 10-bit digitization channels separated by a relative gain of 16) allows to cover the dynamic range of 16 MeV to 250 GeV.

4 . 3 EMCal Deadtime

Requirement:

The EMCal readout must be deadtimeless out to Level-0 trigger time.

Justification:

The fast detectors in ALICE are to be deadtimeless out to the Level-0 trigger time. In ALICE, the different detector subsystems will be configured to participate simultaneously in different event partitions according to their deadtime. This allows "fast detector events" to be taken while the other detectors are busy to enhance the data sample for these detector subsystems.

5. EMCal TRIGGER

Introduction

The EMCAL must be able to trigger on the following observables in Pb+Pb, p+p and p+A collisions:

A. Jet patch, for the study of jet quenching and the gluon structure of heavy nuclei
B. π^0 and direct γ, for the study of jet quenching and the gluon structure of heavy nuclei
C. Electrons from heavy flavor production to study heavy quark energy loss and electron pairs from quarkonium to study screening effects. Electrons also allow *in situ* cross-calibration between the TPC momentum and the EMCal energy via E/p matching.

To accomplish these physics goals, the following requirements are established.

5 . 1 Calorimeter Trigger Requirements:

5.1.1. Calibration Triggers

Requirement:
LED calibration triggers must be supplied for tracking the time dependence of the absolute calibration of the EMCal and for determination of the timing calibration.

Justification:
The EMCal must be calibrated and the associated data must be passed to the DAQ.

5.1.2. Shower Trigger

Requirement :
Identify events in which any overlapping 4x4 tower region corresponding to a single photon or high p_T π^0 merged photon shower is above one of three programmable thresholds without introducing deadtime. This

trigger is to be available at Level-0 and Level-1.

Justification:
Selection of e/γ events or high p_T π^0 events via their signature of a highly localized energy deposition. The three thresholds allow for prescaling of the lower p_T event triggers over a range of p_T. The condition of no deadtime is required to maximize the effective integrated luminosity. The trigger will be used as input to the ALICE Level-0 trigger decision in p+p and Level-1 in Pb+Pb.

5.1.3. Patch Trigger

Requirement :
Identify events in which the sum EMCal energy over a large region, or patch, of towers of programmable size is above a set of programmable thresholds without introducing deadtime. The patch regions overlap to provide uniform spatial trigger response. This trigger information is to be available at Level-1 and Level-2.

Justification:
This is an effective jet trigger. The condition of no deadtime is required to optimize the maximum effective integrated luminosity.

5 . 2 Fast Implementation

Requirement:
EMCal must provide trigger input to Level-0 in p+p running for EMCal events of interest, in particular events containing high energy jets and single showers (π^0,γ,e). The trigger rate at Level-1 must not exceed the maximum TPC gating rate.

Justification:
The ALICE minimum bias p+p trigger is efficient for minimum bias events and runs about three orders of magnitude faster than the ALICE event rate to tape. A minimum bias p+p trigger will therefore record only a small fraction of the available signal for rare, hard processes. An EMCal trigger at Level-0 is needed in p+p collisions to collect a significant sample of jets and high momentum π^0,γ and electrons. The Shower Trigger and Patch Trigger will efficiently pass all event types discussed in section 5.0 on to higher level processing to achieve acceptable trigger rates.

5. 3 Trigger Summary Data

Requirement:
The EMCal trigger primitives data will be written to the Final Data Stream in each event.

Justification:
These data are necessary to debug and to monitor the trigger performance. Trigger rates will be set with trigger thresholds which also allow the physics to be done.

5.4 Input To The High Level Trigger

Requirement:
The EMCal will write full resolution, pedestal-subtracted EMCal tower data for events accepted by Level-1 into a memory for use by the ALICE High Level Trigger.

Justification:
The High Level Trigger will need the EMCal data for refined trigger calculations.

5.5 Latency

Requirement:
The full resolution EMCal shall be available to the High Level Trigger in 250 microseconds or less.

Justification:
The maximum transfer time must be as short as possible to allow adequate High Level Trigger processing time.

6 . SLOW CONTROLS

6 . 1 Slow Controls Connection To Detector

Requirement:

There are slow controls inputs to EMCal for the following functions:
- HV Bias settings for the APDs.
- Downloading Front End Electronics FPGA code.
- Downloading Trigger Region Unit FPGA code.
- Downloading ALTRO chip ADC signal processing parameters.
- Downloading Trigger thresholds and bad channel lists.
- Downloading Clock Offsets for readout.
- System Initialization.
- Calibration.
- LED pulse control (trigger setup, timing, amplitude, pattern).
- Monitor local EMCal temperatures.
- Monitor crate voltages

Justification: These functions are needed for routine operation.

6.2 Slow Controls Connection To High Level Readout

Requirement:

There are slow controls inputs to the electronics on the cart for the following functions:
- Pedestal downloading
- Begin run functions
- Buffer clearing
- Bad channel list downloading to the High Level Trigger and Data Collector
- Run Header information download to Data Collector

Justification:
These services are needed for routine functions implemented for the ALICE readout.

Appendix B

ALICE USA EMCal R&D WBS

	Version 1.7 6-29-05	R&D Phase FY05 to FY08					
WBS Number	**WBS Name**	Total **Contingency**	**Total Project Cost**	**FY05 Cost**	**FY06 Cost**	**FY07 Cost**	**FY08 Costs**
1	**ALICE-USA EMCAL**	**$555,182**	**$4,245,969**	**$169,434**	**$1,132,536**	**$2,515,065**	**$428,935**
1.1	**Detector Prototype**	**$40,622**	**$136,906**	**$324**	**$136,581**	**$0**	
1.1.1	Mechanical Analysis/Prototypes	$5,370	$32,646	$2,127	$30,519	$0	
1.1.1.1	Module Studies	$320	$2,127	$2,127	$0	$0	$0
1.1.1.1.1	Prototypes	$320	$2,127	$2,127	$0	$0	$0
1.1.1.1.2	FEA	$0	$0	$0	$0	$0	$0
1.1.1.2	Super Module Studies	$5,051	$30,519	$0	$30,519	$0	$0
1.1.1.2.1	Prototypes	$5,051	$30,519	$0	$30,519	$0	$0
1.1.1.2.2	FEA	$0	$0	$0	$0	$0	$0
1.1.2	Tower Optical Studies	$4,120	$17,954	$2,573	$15,381	$0	
1.1.2.1	Fiber Bundle/Coupling	$3,570	$15,202	$1,198	$14,005		
1.1.2.1.1	Cryogenic Polishing Tools	$1,027	$4,351		$4,351		
1.1.2.1.2	Aluminizing tools	$2,299	$9,654		$9,654		
1.1.2.1.3	Prototype Studies	$244	$1,198	$1,198			
1.1.2.2	Scintillator Treatment	$550	$2,752	$1,376	$1,376		
1.1.2.2.1	Diffuse reflector studies/comparisons	$409	$2,054	$1,027	$1,027		
1.1.2.2.2	Prototype Edge Treatment	$141	$697	$349	$349		
1.1.3	Prototype Construction	$27,735	$183,529	$75,123	$108,405	$0	$0
1.1.3.1	Pb Radiator	$6,842	$46,903	$27,088	$19,816	$0	$0
1.1.3.1.1	Design	$158	$939	$939			
1.1.3.1.2	Procure	$1,843	$16,566	$16,566			
1.1.3.1.3	Tooling	$1,929	$9,583	$9,583			
1.1.3.1.4	Fabricate	$2,872	$19,352		$19,352		
1.1.3.1.5	QA/QC	$39	$464		$464		
1.1.3.2	Scintillator	$5,535	$34,501	$7,367	$27,134		
1.1.3.2.1	Design	$158	$939	$939			
1.1.3.2.2	Procure	$712	$6,428	$6,428			
1.1.3.2.3	Tooling	$802	$4,074		$4,074		
1.1.3.2.4	Fabricate	$3,810	$22,580		$22,580		
1.1.3.2.5	QA/QC	$53	$480		$480		
1.1.3.3	Structures	$5,417	$36,212	$19,975	$16,237		
1.1.3.3.1	Design	$810	$5,455	$5,455			
1.1.3.3.2	Procure	$1,221	$11,153	$11,153			
1.1.3.3.3	Tooling	$647	$3,367	$3,367			
1.1.3.3.4	Fabricate	$2,740	$16,237		$16,237		
1.1.3.4	Fibers	$6,459	$39,148	$20,694	$18,454		
1.1.3.4.1	Design	$270	$1,600	$1,600			
1.1.3.4.2	Procure	$2,515	$19,094	$19,094			
1.1.3.4.3	Tooling	$805	$3,645		$3,645		
1.1.3.4.4	Cookie Fab	$195	$978		$978		
1.1.3.4.5	Fiber Prep	$1,140	$5,792		$5,792		
1.1.3.4.6	Fiber Bundle Fab	$285	$1,448		$1,448		
1.1.3.4.7	Mixer Fab	$1,157	$5,865		$5,865		
1.1.3.4.8	QA/QC	$92	$727		$727		
1.1.3.5	Final Assembly	$2,646	$11,314	$0	$11,314		
1.1.3.5.1	Tooling	$1,526	$6,342		$6,342		
1.1.3.5.2	Stacking/welding	$757	$3,278		$3,278		
1.1.3.5.3	Fibers/Mixer/APD/PA	$363	$1,694		$1,694		
1.1.3.6	Calibration and Test	$837	$4,450	$0	$4,450		
	Cosmic pre-calibration	$837	$4,450		$4,450		
1.1.3.7	Electronics/APD's R&D	$0	$11,000		$11,000		
1.1.4	Prototype Test Beam	$3,396	$22,277	$0	$22,277	$0	
1.1.4.1	Site Supplies and services	$170	$1,287	$0	$1,287	$0	
1.1.4.1	Shipping/Rigging	$1,528	$7,534	$0	$7,534	$0	
1.1.4.1	Technicians	$1,697	$13,456	$0	$13,456	$0	

	A	B	C	X	AC	AD	AE	AF	AG
67									
68		1.1.5	Institutional Contribution		-$119,500	-$79,500	-$40,000		
69									
70		**1.2**	**EMCal Integration**	**$24,323**	**$286,997**	**$34,812**	**$176,464**	**$75,721**	**$0**
71									
72		1.2.1	EMCal Detector Integration	$13,617	$79,702	$19,925	$59,776	$0	
73		1.2.1.1	Design/Data Base Work	$11,023	$65,331	$16,333	$48,998		
74		1.2.1.2	Prototypes	$2,258	$10,318	$2,579	$7,738		
75		1.2.1.3	EA Travel	$335	$4,054	$1,013	$3,040		
76		1.2.2	Pre-CDR/TDR Work	$10,707	$59,548	$14,887	$44,661	$0	
77		1.2.2.1	Support Structure Integration Concept	$5,291	$28,170	$7,043	$21,128		
78		1.2.2.2	Super Module Integration Concept	$3,816	$22,616	$5,654	$16,962		
79		1.2.2.3	Prototypes	$1,600	$8,761	$2,190	$6,571		
80		1.2.3	WSU Detector Integration @ CERN	$0	$147,748	$0	$72,027	$75,721	
81		1.2.4	Institutional Contribution		$0	$0			
82									
83		**1.3**	**Process Engineering**	**$58,456**	**$338,816**	**$0**	**$180,671**	**$158,145**	
84									
85		1.3.1	Injection Molded Parts	$30,062	$180,671	$0	$180,671	$0	
86		1.3.1.1	Scintillator Tiles	$6,907	$36,622		$36,622		
87		1.3.1.1.1	Design	$607	$4,091		$4,091		
88		1.3.1.1.2	Tool & Die Work	$4,467	$18,209		$18,209		
89		1.3.1.1.2	WSU Tooling	$731	$3,135		$3,135		
90		1.3.1.1.2	Prototypes	$782	$6,910		$6,910		
91		1.3.1.1.3	Shipping/Customs	$320	$4,277		$4,277		
92		1.3.1.2	Optical Mixer	$2,330	$12,127		$12,127		
93		1.3.1.2.1	Design	$246	$1,789		$1,789		
94		1.3.1.2.2	Tool & Die Work	$1,761	$8,631		$8,631		
95		1.3.1.2.3	Prototypes	$322	$1,707		$1,707		
96		1.3.1.3	Fiber guide	$1,170	$6,451		$6,451		
97		1.3.1.3.1	Design	$246	$1,789		$1,789		
98		1.3.1.3.2	Tool & Die Work	$601	$2,955		$2,955		
99		1.3.1.3.3	Prototypes	$322	$1,707		$1,707		
100		1.3.1.4	Fiber Grommet	$1,402	$7,586		$7,586		
101		1.3.1.4.1	Design	$246	$1,789		$1,789		
102		1.3.1.4.2	Tool & Die Work	$833	$4,090		$4,090		
103		1.3.1.4.3	Prototypes	$322	$1,707		$1,707		
104		1.3.1.5	Fiber Cover	$1,590	$8,509		$8,509		
105		1.3.1.5.1	Design	$246	$1,789		$1,789		
106		1.3.1.5.2	Tool & Die Work	$1,021	$5,013		$5,013		
107		1.3.1.5.3	Prototypes	$322	$1,707		$1,707		
108		1.3.1.6	Rear Matrix Plate	$4,193	$21,536		$21,536		
109		1.3.1.6.1	Design	$370	$2,683		$2,683		
110		1.3.1.6.2	Tool & Die Work	$3,501	$17,145		$17,145		
111		1.3.1.6.3	Prototypes	$322	$1,707		$1,707		
112		1.3.1.7	Front Matrix plate	$4,193	$21,536		$21,536		
113		1.3.1.7.1	Design	$370	$2,683		$2,683		
114		1.3.1.7.2	Tool & Die Work	$3,501	$17,145		$17,145		
115		1.3.1.7.3	Prototypes	$322	$1,707		$1,707		
116		1.3.1.8	Front Cover	$2,087	$11,859		$11,859		
117		1.3.1.8.1	Design	$246	$1,789		$1,789		
118		1.3.1.8.2	Tool & Die Work	$1,518	$8,364		$8,364		
119		1.3.1.8.3	Prototypes	$322	$1,707		$1,707		
120		1.3.1.9	Module Mounting Plate	$3,613	$18,698		$18,698		
121		1.3.1.9.1	Design	$370	$2,683		$2,683		
122		1.3.1.9.2	Tool & Die Work	$2,921	$14,307		$14,307		
123		1.3.1.9.3	Prototypes	$322	$1,707		$1,707		
124		1.3.1.10	Engineering Oversight	$2,579	$35,748		$35,748		
125									
126		1.3.2	Laser Cut/Stamped Parts	$28,394	$158,145	$0	$0	$158,145	
127		1.3.2.1	Pb Radiator Plates	$21,096	$105,787			$105,787	
128		1.3.2.1.1	Design	$832	$6,037			$6,037	
129		1.3.2.1.2	Vendor Tooling	$16,274	$79,655			$79,655	
130		1.3.2.1.3	WSU Tooling	$2,663	$11,001			$11,001	
131		1.3.2.1.4	Materials	$223	$2,483			$2,483	
132		1.3.2.1.5	Prototypes	$1,104	$6,610			$6,610	

	A	B	C	X	AC	AD	AE	AF	AG
130		1.3.2.1.3	WSU Tooling	$2,663	$11,001			$11,001	
131		1.3.2.1.4	Materials	$223	$2,483			$2,483	
132		1.3.2.1.5	Prototypes	$1,104	$6,610			$6,610	
133		1.3.2.2	Front Compression Plate	$3,133	$17,405			$17,405	
134		1.3.2.2.1	Design	$524	$3,801			$3,801	
135		1.3.2.2.2	Vendor Tooling	$1,844	$9,035			$9,035	
136		1.3.2.2.3	Prototypes	$766	$4,568			$4,568	
137		1.3.2.3	Rear Compression Plate	$3,133	$17,405			$17,405	
138		1.3.2.3.1	Design	$524	$3,801			$3,801	
139		1.3.2.3.2	Vendor Tooling	$1,844	$9,035			$9,035	
140		1.3.2.3.3	Prototypes	$766	$4,568			$4,568	
141		1.3.2.4	Engineering Oversight	$1,032	$17,549			$17,549	
142									
143									
144		**1.4**	**EMCal Support Structure**	**$159,071**	**$1,066,500**	**$63,036**	**$223,582**	**$779,883**	
145									
146		1.4.1	EMCal Support Structure Design	$24,978	$215,582	$63,036	$152,547	$0	
147		1.4.1.1	Design Costs (WSU)	$1,523	$12,187	$12,187	$0	$0	
148		1.4.1.1.1	EA Labor	$293	$1,848	$1,848			
149		1.4.1.1.2	EA Travel	$197	$3,829	$3,829			
150		1.4.1.1.3	EN Labor	$1,033	$6,510	$6,510			
151		1.4.1.2	Design Costs (LBL)	$23,455	$203,395	$50,849	$152,547		
152		1.4.1.2.1	EA Labor	$14,700	$127,473	$31,868	$95,604.45		
153		1.4.1.2.2	EN Labor	$8,755	$75,923	$18,981	$56,942.08		
154									
155		1.4.2	Module Support Structure CERN Procurement	$123,955	$789,531	$0	$9,648	$779,883	
156		1.4.2.1	Procurement - WSU Costs	$908	$9,648	$0	$9,648	$0	
157		1.4.2.1.1	EA Labor	$153	$1,671		$1,671		
158		1.4.2.1.2	EA Travel	$218	$2,093		$2,093		
159		1.4.2.1.3	EN Labor	$537	$5,885		$5,885		
160		1.4.2.2	Procurement - CERN Costs	$123,047	$779,883		$0	$779,883	
161		1.4.2.2.1	EA Labor	$0	$0		$0		
162		1.4.2.2.2	Support Structure	$123,047	$779,883		$0	$779,883	
163									
164		1.4.3	Support Structure Installation/Test	$10,138	$61,387	$0	$61,387	$0	
165		1.4.3.1	Installation - WSU Costs	$3,427	$33,555		$33,555		
166		1.4.3.1.1	EN Oversight	$1,250	$12,824		$12,824		
167		1.4.3.1.2	EA Labor	$332	$3,409		$3,409		
168		1.4.3.1.3	TE Labor	$605	$6,205		$6,205		
169		1.4.3.1.4	EA/TE Travel	$1,240	$11,116		$11,116		
170		1.4.3.2	Installation - CERN Costs	$6,711	$27,832		$27,832		
171		1.4.3.2.1	EA Labor	$276	$1,624		$1,624		
172		1.4.3.2.2	LHC Riggers	$6,435	$26,209		$26,209		
173									
174									
175		**1.5**	**Super Module**	**$204,814**	**$1,026,150**	**$0**	**$0**	**$946,623**	**$79,528**
176									
177		1.5.1	Super module design	$31,728	$269,898	$0	$0	$269,898	$0
178		1.5.1.1	EA Labor (LBL)	$14,700	$127,473	$0	$0	$127,473	$0
179		1.5.1.2	EN Labor (LBL)	$8,755	$75,923	$0	$0	$75,923	$0
180		1.5.1.3	Travel and supplies (LBL)	$3,570	$27,027	$0	$0	$27,027	$0
181		1.5.1.4	EN Labor (WSU travel, labor)	$4,703	$39,476	$0	$0	$39,476	$0
182									
183		1.5.2	Parts and Components	$74,620	$318,164	$0	$0	$318,164	$0
184		1.5.2.1	Module parts	$33,890	$192,382	$0	$0	$192,382	$0
185		1.5.2.1.1	Front Plate	$383	$2,148	$0	$0	$2,148	$0
186		1.5.2.1.2	Front Weld Plate	$762	$4,545	$0	$0	$4,545	$0
187		1.5.2.1.3	Back Plate	$383	$2,148	$0	$0	$2,148	$0
188		1.5.2.1.4	Al varient of back plate	$15	$92	$0	$0	$92	$0
189		1.5.2.1.5	Al varient of frontplate	$15	$92	$0	$0	$92	$0
190		1.5.2.1.6	Back Weld Plate	$762	$4,545	$0	$0	$4,545	$0
191		1.5.2.1.7	Strap	$947	$5,864	$0	$0	$5,864	$0
192		1.5.2.1.8	Grommet	$408	$2,285	$0	$0	$2,285	$0
193		1.5.2.1.9	Fiber covers	$511	$2,849	$0	$0	$2,849	$0
194		1.5.2.1.10	Module Mount	$1,182	$6,869	$0	$0	$6,869	$0
195		1.5.2.1.11	Scintillator Tile	$4,319	$24,228	$0	$0	$24,228	$0
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

	B	C	X	AC	AD	AE	AF	AG
196	1.5.2.1.12	Lead Absorber	$13,555	$74,699	$0	$0	$74,699	$0
197	1.5.2.1.13	Tyvek Sheet	$532	$2,965	$0	$0	$2,965	$0
198	1.5.2.1.14	Fibers	$7,424	$43,738	$0	$0	$43,738	$0
199	1.5.2.1.15	Light guide / diffuser	$1,082	$6,018	$0	$0	$6,018	$0
200	1.5.2.1.17	LED, Optical fibers and prisms	$1,609	$9,299	$0	$0	$9,299	$0
201	1.5.2.2	Super Module parts	$40,730	$125,782	$0	$0	$125,782	$0
202	1.5.2.2.1	Eta Spine Zero*	$6,303	$25,220	$0	$0	$25,220	$0
203	1.5.2.2.2	Eta Spine Mid*	$0	$0	$0	$0	$0	$0
204	1.5.2.2.3	Eta Spine End*	$0	$0	$0	$0	$0	$0
205	1.5.2.2.4	Super Back	$34,084	$95,350	$0	$0	$95,350	$0
206	1.5.2.2.5	fasteners	$343	$5,212	$0	$0	$5,212	$0
207								
208	1.5.3	Assembly	$82,884	$358,561	$0	$0	$358,561	$0
209	1.5.3.1	Assembly Tooling and supplies	$71,503	$265,243	$0	$0	$265,243	$0
210	1.5.3.1.1	module assembly tooling	$11,262	$41,200	$0	$0	$41,200	$0
211	1.5.3.1.2	Super mod assy tooling -WSU	$19,423	$63,632	$0	$0	$63,632	$0
212	1.5.3.1.3	Lead handling assembly fixtures	$8,739	$31,861	$0	$0	$31,861	$0
213	1.5.3.1.4	Lead Environmental Controls	$26,235	$94,450	$0	$0	$94,450	$0
214	1.5.3.1.5	Assembly supplies	$1,113	$7,111	$0	$0	$7,111	$0
215	1.5.3.1.6	RTV System and Supplies	$1,605	$13,590	$0	$0	$13,590	$0
216	1.5.3.1.7	Module Shipping Fixtures	$3,127	$13,399	$0	$0	$13,399	$0
217	1.5.3.2	Detector Assembly	$11,381	$93,318	$0	$0	$93,318	$0
218	1.5.3.2.1	stacking modules	$711	$9,043	$0	$0	$9,043	$0
219	1.5.3.2.2	machine modules	$2,452	$17,798	$0	$0	$17,798	$0
220	1.5.3.2.3	welding	$1,466	$12,709	$0	$0	$12,709	$0
221	1.5.3.2.4	fiber insertion	$970	$9,369	$0	$0	$9,369	$0
222	1.5.3.2.5	fiber cover fiber bundle and epoxy	$1,121	$12,274	$0	$0	$12,274	$0
223	1.5.3.2.6	polish fiber attach mixer	$1,810	$13,143	$0	$0	$13,143	$0
224	1.5.3.2.7	attach APD	$366	$3,177	$0	$0	$3,177	$0
225	1.5.3.2.8	close up	$366	$3,177	$0	$0	$3,177	$0
226	1.5.3.2.9	assemble spine	$1,875	$10,509	$0	$0	$10,509	$0
227	1.5.3.2.10	pack	$244	$2,118	$0	$0	$2,118	$0
228	1.5.4	Installation	$15,581	$79,528	$0	$0	$0	$79,528
229	1.5.4.3	Site Supplies and Services	$255	$1,931	$0	$0	$0	$1,931
230	1.5.4.4	Module Installation (WSU Costs)	$1,632	$9,540	$0	$0	$0	$9,540
231	1.5.4.5	Module Installation - CERN Costs	$850	$6,435	$0	$0	$0	$6,435
232	1.5.4.6	Electronics Installation fixtures	$1,215	$5,531	$0	$0	$0	$5,531
233	1.5.4.7	Electronics Installation institutional cost	$1,377	$10,425	$0	$0	$0	$10,425
234	1.5.4.8	Site tools, fixtures, test equipment and supplie	$2,338	$19,825	$0	$0	$0	$19,825
235	1.5.4.9	Module transportation and handling	$7,266	$23,369	$0	$0	$0	$23,369
236	1.5.4.10	Module Storage Facility at CERN	$649	$2,473	$0	$0	$0	$2,473
237								
238								
239	**1.6**	**Module and Component Test**	**$11,571**	**$53,865**	**$0**	**$0**	**$53,865**	**$0**
240								
241	1.6.1	Tests and Analysis	$11,571	$53,865	$0	$0	$53,865	$0
242	1.6.1.1	APD Test	$4,561	$21,459			$21,459	$0
243	1.6.1.2	Cosmic Ray test/calibrate	$7,010	$32,407			$32,407	$0
244								
245	**1.7**	**Electronics**	**$26,131**	**$198,409**	**$0**	**$0**	**$0**	**$198,409**
246	1.7.1	Electronics Procurement	$26,131	$323,409	$125,000	$0	$0	$198,409
247	1.7.1.1	Preamp	$6,012	$41,432	$0	$0	$0	$41,432
248	1.7.1.2	Pre Amp Cable	$815	$3,998	$0	$0	$0	$3,998
249	1.7.1.3	FEE	$3,741	$35,779	$0	$0	$0	$35,779
250	1.7.1.4	Fee Crates	$746	$7,147	$0	$0	$0	$7,147
251	1.7.1.5	TRU	$567	$5,429	$0	$0	$0	$5,429
252	1.7.1.6	RCU	$299	$2,868	$0	$0	$0	$2,868
253	1.7.1.7	TRU to RCU cables	$45	$198	$0	$0	$0	$198
254	1.7.1.8	RCU to DAQ Fibers	$1,702	$6,943	$0	$0	$0	$6,943
255	1.7.1.9	HV supplies NIM Modules	$22	$213	$0	$0	$0	$213
256	1.7.1.10	HV NIM Bins	$19	$209	$0	$0	$0	$209
257	1.7.1.13	HV Cables and Connectors	$71	$461	$0	$0	$0	$461
258	1.7.1.14	Internal Cables	$982	$3,493	$0	$0	$0	$3,493
259	1.7.1.16	LED Driver	$2,523	$8,119	$0	$0	$0	$8,119
260	1.7.1.17	Electronics test/calibrate	$0	$0	$0	$0	$0	$0
261	1.7.1.18	APD's	$8,588	$82,122	$0	$0	$0	$82,122

	B	C	X	AC	AD	AE	AF	AG
262	1.7.1.19	Electronics R&D		$125,000	$125,000		$0	$0
263	1.7.2	Institutional Contribution		-$125,000	-$125,000	$0	$0	$0
264	1.7.3	Electronics Test Calibrate	$0	$0	$0	$0		
265								
266	**1.8**	**EMCal Software**	**$0**	**$0**	**$0**	**$0**	**$0**	
267	1.8.1	EMCal Contribution to on line	$0	$0	$0	$0	$0	
268	1.8.1.1	Software	$0	$0		$0	$0	
269	1.8.1.2	Travel	$0	$0		$0	$0	
270	1.8.1.3	Materials/Supplies	$0	$0		$0	$0	
271	1.8.2	EMCal Contribution to off line	$0	$0	$0	$0	$0	
272	1.8.2.1	Software	$0	$0			$0	
273	1.8.2.2	Travel	$0	$0			$0	
274	1.8.2.3	Supplies	$0	$0			$0	
275	1.8.3	Institutional Contribution	$0	$0	$0	$0	$0	
276								
277								
278	**1.9**	**EMC Conv. Sys.**	**$9,874**	**$76,777**	**$0**	**$0**	**$76,777**	**$0**
279	1.9.1	FEE Water Cooling	$6,671	$62,746	$0	$0	$62,746	
280	1.9.1.1	Water cooled heat exchangers	$2,528	$21,662			$21,662	
281	1.9.1.2	Tubing, connectors, Misc. parts	$2,396	$20,847			$20,847	
282	1.9.1.3	Electrical supplies	$1,251	$10,617			$10,617	
283	1.9.1.4	Travel	$495	$9,620			$9,620	
284	1.9.2	LV Power and Control	$3,203	$14,031	$0	$0	$14,031	
285	1.9.2.1	Module LV Power Blocks	$278	$1,241			$1,241	
286	1.9.2.2	LV Cables and Connectors	$849	$3,520			$3,520	
287	1.9.2.3	LV DC Power Supplies	$2,077	$9,270			$9,270	
288								
289	**1.10**	**Project Management and Integration**	**$20,320**	**$1,061,548**	**$71,262**	**$415,238**	**$424,052**	**$150,997**
290	1.10.1	WSU Project Management	$20,320	$405,124	$9,001	$157,155	$157,155	$81,814
291	1.10.2.1	WSU Purchasing / budget tracking / personnel ma	$9,425	$209,795	$0	$83,918	$83,918	$41,959
292	1.10.2.1.1	Office Assistant	$822	$18,301	$0	$7,320	$7,320	$3,660
293	1.10.2.1.2	Administrative Assistant	$8,603	$191,494	$0	$76,598	$76,598	$38,299
294	1.10.2.2	Contract project manager	$4,121	$91,723	$0	$30,574	$30,574	$30,574
295	1.10.2.3	WSU Travel (integration and management)	$5,353	$90,011	$9,001	$36,004	$36,004	$9,001
296	1.10.2.4	WSU Office Supplies	$293	$2,797	$0	$1,259	$1,259	$280
297	1.10.2.5	WSU Postage and shipping (Fed. Ex., etc.)	$325	$3,108	$0	$1,554	$1,554	
298	1.10.2.6	WSU Review and Proposal Expenses	$804	$7,691	$0	$3,846	$3,846	
299	1.10.3	LBNL Deputy Contract Project Manager	$0	$656,424	$62,261	$258,083	$266,897	$69,183
300	1.10.4	Institutional Contribution		$0		$0	$0	$0
301								
302	**1.11**	**Computing**		**$0**	**$0**	**$0**	**$0**	**$0**

Appendix C WBS Dictionary (DRAFT 6-30-05)

WBS Number	WBS Dictionary Entry
1	**ALICE-USA EMCAL R&D**
1.1	**Detector Prototype** **A 64 tower detector prototype including FEE for use in electron and hadron test beams**
1.1.1	Mechanical Analysis/Prototypes * Mechanical studies of detector modules stability using Finite Element Analysis and prototypes * Mechanical studies of detector super module stability using Finite Element Analysis and prototypes
1.1.2	Tower Optical Studies * Design and fabrication of tools necessary to bulk polish WLS fibers under cryogenic conditions * Design and fabrication of tools necessary to bulk aluminize one end of the WLS fibers * Fabrication of fiber bundle prototypes and studies of optical coupling efficiency and uniformity
1.1.3	Prototype Construction * Design, fabrication and QA/QC of 64 tower prototype components including radiators, scintillator tiles, mechanical structures, WLS fiber bundles. * Final assembly of the 64 tower prototype * Calibration and cosmic ray testing of the 64 tower prototype * Procurement and integration of APD and FEE with the 64 tower prototype * Test beam measurements with the 64 tower prototype in the FNAL test beam * This WBS includes an institutional contribution of $90k
1.2	**EMCal Integration** **Design and prototype work needed to ensure integration of the EMCal with the ALICE detector**
1.2.1	EMCal Detector Integration * Design and database work necessary to secure EMCal integration volumes for the detector itself, LV power and associated cable runs, HV power and associated cable runs, water chillers and associate plumbing runs FEE electronics crates and associated fiber readout runs and communication cabling. * Prototypes of the above features as required to verify adequacy of stay clear zones, etc. * Support for travel to CERN for the principal engineering associate charged with leading the US side of this integration effort * This WBS includes an institutional contribution of $42k
1.2.2	Pre-CDR/TDR Work * Pre-CDR leading to the development of a support structure concept and integration plan prepatory to engineering design work * Pre-CDR leading to the development of a super module integration and installation plan prepatory to engineering design work * Prototypes and/or models of the above features as required.
1.2.3	Detector Integration at CERN * Full time integration physicist cited at CERN to represent EMCal to the ALICE technical board and integration committee during ALICE construnction and assembly
1.3	**Process Engineering** **Design and prototype work necessary to mass produce EMC parts and components in industry**
1.3.1	Injection Molded Parts * Mold design and fabrication for those calorimeter parts that are mass produced by plastic injection molding. * prototype production of all injection molded calorimeter parts * QA/QC of all industry produced prototypes to certify production readiness
1.3.2	Laser Cut/Stamped Parts * Tool and Die work for calorimeter parts that are mass produced by metal stamping or laser cutting. * prototype production of all stamped calorimeter parts * QA/QC of all industry produced prototypes to certify production readiness
1.4	**EMCal Support Structure** **Design, procure, install and test the ALICE-USA EMCal support structure**
1.4.1	EMCal Support Structure Design * Joint engineering effort involving CERN, LBNL and WSU leading to a production ready design for the EMCal support structure along with all necessary installation tooling. * Finite element analysis of the final design

1.4.2 Module Support Structure CERN Procurement

* Procurement by CERN of the EMCal support structure in close collaboration with LBNL and WSU project management and engineering staff.

1.4.3 Support Structure Installation/Test

* Installation of the EMCal support structure using LHC riggers with cognizant oversight by WSU engineering and project management
* Load and stability testing of the installed support structure

1.5 Super Module

Production, installation and test of the first EMCal super module

1.5.1 Design

* Costs fo engineering labor

1.5.2 Parts and Components

* Mass production of all components associated with the modules that make up the first super module and all components associated with the integration of the first super module

1.5.3 Assembly

* Design and fabrication of tooling associated with module and super module assembly
* Design and fabrication of Lead handling fixtures
* Installation and checkout of Lead environmental controls
* Assembly of individual detector modules
* Assembly of super module, pack and ship

1.5.4 Installation

* Module transportation and handling
* Site supplies and services required at installation time including rigging, tools, etc
* Joint CERN/WSU/LBNL super module installation
* Electronics Installation fixtures and electronics Installation institutional costs
* procurement of EMCal dedicated tools, fixtures, test equipment and supplies needed at the CERN site
* Module storage facility and/or fixtures required at CERN between unpacking and lifting for installation

1.6 Module and Component Test

Testing and pre-calibration of all APDs and all individual EMCal modules

1.6.1 Tests and Analysis

* Testing of all APD's to establish noise parameters and determine gain/bias curve using a calibrated light source with very long term stability
* module cosmic ray testing for the purpose of constructing a starting calibration data base 64 tower units will be tested simultaneously for ~ 24 hours each

1.7 Electronics

EMCal electronics procurement and test

1.7.1 Electronics Procurement

* Finalize design of EMCal specific variances from PHOS electronics
* Procurement of all EMCal electronics components for the first super module beginning with the APD itself through to the trigger processor and the DAQ receiver.
* Slow controls software for initialization, trigger setup, etc
* Slow controls software for state monitoring and fault detection, etc.

1.7.2 Electronics Test Calibrate

* Test and calibration of all EMCal electronics including analog and digital functions.

1.8 EMCal Software

Software engineering for EMCal online and offline

1.8.1 EMCal Contribution to on line

* EMCal specific software as a component of the ALICE online system
  At a minimum this software will allow:
* Online construction and analysis of mip spectra of high PT hadrons for gain balancing
* Online construction and analysis of calibration monitoring spectra such as LED spectra, pedestal spectra, etc.
* Online cosmic ray spectra and analysis
* Online trigger monitoring spectra

1.8.2 EMCal Contribution to off line

* EMCal specific software as a component of the ALICE reconstruction and offline system
  At a minimum this software will allow:
* Offline construction and analysis of mip spectra of high PT hadrons for gain balancing and absolute calibration
* Offline cosmic ray spectra and analysis with TPC tracking
* Offline reconstruction of photonic electron spectra for absolute calibration
* Offline reconstruction of neutral pion spectra for absolute calibration

1.9 EMC Conv. Sys.

Conventional systems and control required for EMCal operation. This includes crate cooling, LV power and distribution, fault detection and handling, etc.

1.9.1 FEE Water Cooling

* Chiller system
* Water cooled heat exchangers at crates
* All necessary tubing, connectors and parts plus labor required to assemble the entire leakless cooling system
* hardware and software required for slow controls

1.9.2 LV Power and Control

* complete FEE LV power system including LV power supplies, cables and connectors
* dedicated hardware fault monitoring system for above\
* hardware and software required for slow controls

1.10 Project Management and Integration

Personnel and project office expenses at Wayne State and LBNL.

1.10.1 WSU Project Management

* Personnel and office expenses associated with the project office administration. This covers personnel management for the calorimeter factory, payroll, purchasing, subcontracts, budget tracking and visas for foreign participants. All of these activities are charged as a direct cost at WSU
* Expenses associated with Contract Project Manager reduced teaching responsibility and travel to CERN and LBL.
* Office supplies, postage and review and proposal expenses. The latter includes travel to review sites.

1.10.2 Deputy Contract Project Manager

* Expenses associated with the LBNL senior engineer who will function as Deputy Contract Project Manager

1.11 Computing

* Costs are budgeted here to allow a modest upgrade of PDSF during the construction phase to meet ALICE-USA computing needs